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AN INDEX TO ASSESS THE SENSITIVITY OF GULF OF MEXICO SPECIES TO CHANGES IN ESTUARINE SALINITY REGIMES

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ABSTRACT An index of biological sensitivity to changes in freshwater inflow was developed for 44 species in 22 Gulf of Mexico estuaries for adult and juvenile life stages of fishes and macroinvertebrates. The BioSalinity Index (BSI) provides an innovative approach to quantify estuary-specific sensitivity of organisms to changes in estuarine salinity regimes based upon our knowledge of species salinity habitat preferences, the availability of this preferred habitat, and the relative abundance and distribution of species in time and space. We found that a significant difference exists between adult and juvenile life stage sensitivity, with juveniles exhibiting a lower sensitivity to salinity changes than adults, and that a considerable disparity exists in species-specific sensitivities among Gulf estuaries. Likewise, when the full complement of 44 species-level BSIs are averaged, marked differences in assemblage-wide sensitivity are evident across estuaries. The availability of preferred salinity habitat had a greater influence on the BSI for estuarine species than did their relative abundance and temporal distribution. The BSI was applied by members of a 1995 Gulf of Mexico freshwater inflow workshop to identify a subset of estuaries which appear more sensitive to freshwater inflow changes and are candidates for further study.

INTRODUCTION

The effects of changes in freshwater inflow on estuarine systems and their associated biological communities are of great interest to coastal living resource managers. Most efforts to predict changes in estuarine and near-shore community structure in response to environmental stress are directed towards describing species responses to habitat alteration and point and/or non-point source pollutant discharge, not to system-wide changes in hydrological character (Hoff and Ibara 1977). This paper is intended to address this information gap and to describe the development of an objective method to predict and assess both species and estuary-level response to shifts in estuarine salinity structure. Our approach was applied to U.S. Gulf of Mexico estuaries to assess the bio-sensitivity of species and their estuarine distribution based on salinity preferences (Christensen et al. 1996).

Natural episodic fluxes of freshwater are common in U.S. estuaries, and most often result from random meteorological events (Ward 1980; Ward and Armstrong 1980). Literary accounts of altered estuarine community structure in response to storm-induced freshwater pulses are numerous (Drinkwater et al. 1991, Nielsen and Kioerboe 1991; Moffat and Jones 1991; Goeghegan et al 1992), yet most report that physical forcing mechanisms (i.e., tidal flushing and wind induced surface currents), which occur within relatively fine temporal scales, act collectively to reduce the chance for resulting long-term community change.

Anthropogenically derived flow changes into estuaries often are of greater duration (chronic, if not indefinite), and therefore harbor the potential to permanently alter a system's biological community. Man has subjected most of the nation's estuaries and their associated watersheds to significant modifications, including: flow diversions and reservoir construction which significantly alter the volume and/or timing of freshwater delivery to an estuary, creation or deepening of navigation channels which facilitate high-salinity bottom-water intrusion, and large-scale dredge material disposal site construction (including diked disposal islands) which can alter estuarine circulation patterns (Orlando et al. 1993).

It has been suggested that fisheries biologists use freshwater inflow as a tool for fisheries management by providing preferred hydrological conditions for commercially important species. DaSilva (1986) reported that by regulating the Zambizi river runoff in an appropriate manner, Penaeid shrimp yields from the Sofala bank would likely increase and provide a measure of stability and strength to local coastal economies of Mozambique. Although these approaches exhibit great promise, it is imperative that resource managers are able to accurately predict which species would be displaced by such management techniques. Likewise, Ulanowicz and Tuttle (1993) exhibited via an ecosystem model how increasing oyster populations and their associated filtering capacity impact phytoplankton standing crop in Chesapeake Bay. The degree of estuarine community change expected from a permanent alteration

in salinity structure is difficult to predict quantitatively from the existing literature because of the lack of field-based species salinity range data available (Monaco 1995). Moreover, most field reports rely on instantaneous observations, not on long-term assessments of average conditions, and available correlations and experimental information have not been extensive enough to reflect the variety of salinity regimes found at particular sites (Montague and Ley 1993).

The BioSalinity Index (BSI) was conceived as a screening tool for natural resource managers to provide a quantitative estimate of the effect which a measurable shift in salinity structure has on the relative abundance and distribution of a species, as well as on estuarine biological assemblages. The National Oceanic and Atmospheric Administration (NOAA) Strategic Environmental Assessments Division (SEAD) convened a workshop in cooperation with the U.S. Environmental Protection Agency (EPA) Gulf of Mexico Program Freshwater Inflow Committee to identify important relationships between freshwater inflow alteration, estuarine habitat, and biological resources in 29 Gulf estuaries (Christensen et al. 1996; SEA 1995). The BSI was developed specifically for this workshop, and was one of three evaluating/screening tools used synergistically to rank the relative potential for significant changes in estuarine hydrodynamic character and in their associated biological communities among major Gulf of Mexico estuaries. This was the first test of BSI applicability and validity in resource management decision-making.

MATERIALS AND METHODS

The NOAA Estuarine Living Marine Resources Program (ELMR) has spent several years assembling an extensive inventory of the relative abundance and distribution of 44 important finfish and macroinvertebrates in Gulf estuaries, with considerable effort spent on documenting ontogenetic shifts in salinity habitat associations (Nelson 1992; Patillo et al. in preparation). A list of the 44 ELMR species is provided in Table 1. This biological data set, coupled with estuarine salinity information, provided the foundation upon which the BSI was developed for selected Gulf species.

Salinity Zonation

A framework of salinity zonation was developed based on species response to, and partitioning of, the estuarine salinity gradient in nature, and this analysis was a prerequisite in developing the BSI. Biologically-based salinity zone boundaries were defined based on

TABLE 1

List of 44 ELMR species for Gulf of Mexico estuaries

Common name	Scientific name
bay scallop	*Argopecten irradians*
Eastern oyster	*Crassostrea virginica*
Atlantic rangia	*Rangia cuneata*
quahogs	*Mercenaria species*
bay squid	*Lolliguncula brevis*
brown shrimp	*Penaeus aztecus*
pink shrimp	*Penaeus duorarum*
white shrimp	*Penaeus setiferus*
daggerblade grass shrimp	*Palaemonetes pugio*
spiny lobster	*Panulirus argus*
blue crab	*Callinectes sapidus*
Gulf stone crab	*Menippe adina*
stone crab	*Menippe mercenaria*
bull shark	*Carcharhinus leucas*
tarpon	*Megalops atlanticus*
Alabama shad	*Alosa alabamae*
Gulf menhaden	*Brevoortia patronus*
yellowfin menhaden	*Brevoortia smithi*
gizzard shad	*Dorosoma cepedianum*
bay anchovy	*Anchoa mitchilli*
hardhead catfish	*Arius felis*
sheepshead minnow	*Cyprinodon variegatus*
Gulf killifish	*Fundulus grandis*
silversides	*Menidia spp.*
snook	*Centropomus undecimalis*
bluefish	*Pomatomus saltatrix*
blue runner	*Caranx crysos*
crevalle jack	*Caranx hippos*
Florida pompano	*Trachinotus carolinus*
gray snapper	*Lutjanus griseus*
sheepshead	*Archosargus probatocephalus*
pinfish	*Lagodon rhomboides*
silver perch	*Bairdiella chrysoura*
sand seatrout	*Cynoscion arenarius*
spotted seatrout	*Cynoscion nebulosus*
spot	*Leiostomus xanthurus*
Atlantic croaker	*Micropogonias ndulatus*
black drum	*Pogonias cromis*
red drum	*Sciaenops ocellatus*
striped mullet	*Mugil cephalus*
code goby	*Gobiosoma robustum*
spanish mackerel	*Scomberomorus maculatus*
Gulf flounder	*Paralichthys albigutta*
Southern flounder	*Paralichthys lethostigma*

Principal Components Analysis (PCA). This method of defining salinity zones was first introduced by Bulger et al. (1993) for Atlantic estuaries, and Lowery et al. (in preparation) replicated these procedures for the Gulf of Mexico. PCA is the preferred type of factor analysis when the goal is to reduce a large number of variables (e.g., 1 ppt salinity increments) to a smaller set of components, or salinity zones (Tabachnik and Fidell 1989). Correlations between a salinity increment and principal component (varimax rotated component loadings) greater than 0.5 and/or less than -0.5 were assigned to a specific salinity zone (component). The objective of this analysis was to develop a method for defining biologically-relevant estuarine salinity zonations which could be used to assess the potential impacts that changes in salinity may have on species distribution patterns in the northern Gulf of Mexico. An analysis by Lowery et al. (in preparation) was conducted on field-based salinity ranges and co-occurrences of 161 fish species collected from Mississippi Sound, in Mississippi and Mobile Bay and Weeks Bay in Alabama. Data for the analysis were obtained from the Alabama Coastal Area Board (ACAB) baseline survey of Mobile Bay and Mississippi Sound trawl survey from 1982-1991 (Bill Hosking, personal communication), Gulf

Coast Research Laboratory (GCRL) Mississippi trawl survey data from 1982-1994 (James Warren, personal communication and Weeks Bay National Estuarine Research Reserve seine survey data from 1988-1989 (Rick Wallace, personal communication). Field collections were cross referenced with station salinity data to provide a measure of association.

In the analysis by Lowery et al. (in preparation), the original 34 salinity increments were considered as 34 separate variables which collectively explained 100% of the variance in the original data matrix. Application of PCA to the salinity range data indicated that the underlying structure of species distributions along the salinity gradient in Gulf estuaries could be represented by five principal components, which collectively explained 91% of the variance in the original data. Each component had a suite of salinity variables with which it was most highly associated, and each principal component corresponded to a unique biologically-based salinity zone. Plots of varimax rotated loadings (VRL) of the five principal components relative to the original 34 variables (salinity increments) are displayed in Figure 1. Rotation of principal axes is commonly used to maximize the variance explained along each axis and to improve the interpretability and scientific utility of the results without changing the underlying
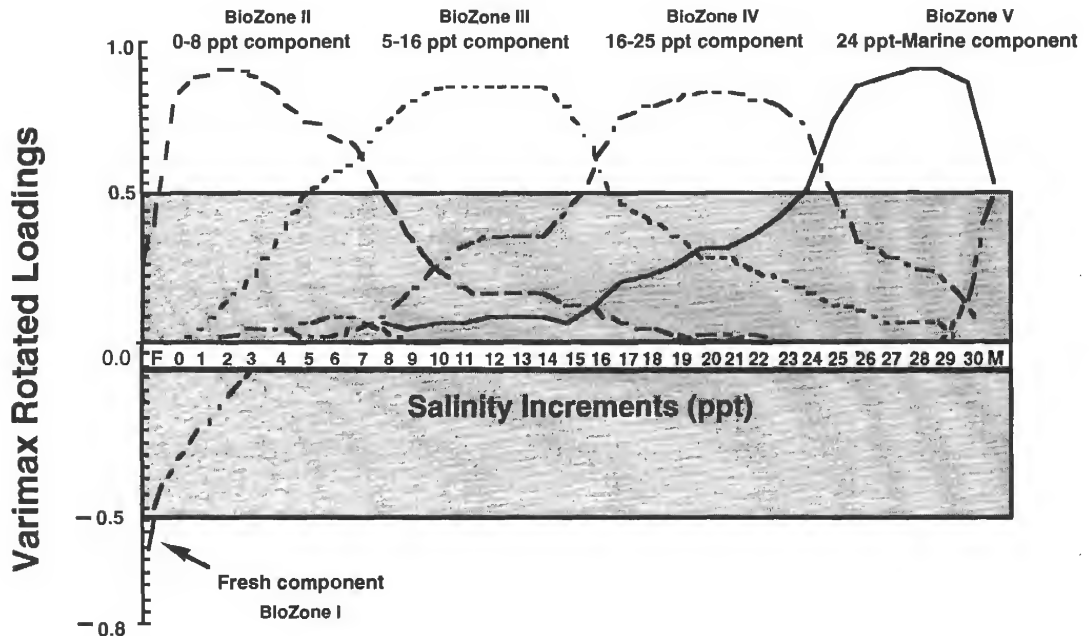

Figure 1. Five biologically-based salinity zones corresponding to principal components (Lowery et al. in preparation)

mathematical properties (Bulger et al. 1993). Component 1 (fresh) consists of waters which typically are inhabited by stenohaline freshwater fishes in areas with little or no tidal influence. Salinity ranges for the remaining overlapping components inhabited by estuarine species are component 2 (0-8ppt), component 3 (5-16ppt), component 4 (16-25), and component 5 (24-marine), which is inhabited primarily by marine species.

Species Abundance and Distribution

Very few states have fisheries monitoring programs with consistent sampling protocols and schedules, and no two states have identical monitoring programs. To allow inter-estuarine BSI comparisons, it was necessary to devise a method to standardize estuarine fish distribution and abundance information across Gulf of Mexico estuaries. This task was undertaken by the NOAA ELMR Program (Nelson 1992). ELMR categorical spatial and temporal distribution and relative abundance data for Gulf estuaries were compiled from data sets, survey reports, and scientific literature on species ecology, behavior, and/or physiology (Monaco 1995). To filter out environmental variability (wet year, cold year, etc.), biological variability (strong vs. weak recruitment year) and anthropogenically induced variation (extreme fishing mortality, sampling error, etc.), information was synthesized to best define current relative abundance and distribution patterns for 44 Gulf species. These abundance estimates were verified through an extensive peer-review process utilizing the knowledge and field experience of Gulf Coast fisheries scientists, managers, and biologists (Nelson 1992).

ELMR relative abundance categories of highly abundant (5), abundant (4), common (3), rare (2), no information (1), and not present (0) were intended to simulate categories often used and regularly encountered

by fisheries biologists. This consistent format is readily understandable by fisheries scientists in the field, resource managers, and academic biologists. An ordinal relative abundance scheme of this type is typically adopted in the field. The abundance of the life-stage of a species was ranked relative to that of the same life-stage of other similar species which, were defined as those species characterized by similar life-history strategies and gear susceptibilities. Catch data for these species were then transformed into categorical ranks using an order of magnitude break.

Species salinity range/tolerance data compiled by the ELMR Program were used to assign 44 Gulf fish and invertebrate relative abundance ranks to the PCA derived biologically-based salinity zones (Patillo et al. in prep). ELMR species spatial and temporal distributions and their monthly relative abundance ranks are organized by three estuarine salinity zones: tidal fresh zone (0-0.5 ppt), mixing zone (0.5-25 ppt), and seawater zone (>25ppt)(Nelson 1992). These salinity zones have been delineated in the NOAA National Estuarine Inventory (NEI) (NOAA 1989). In addition, the ELMR habitat association data also is organized by the Venice system salinity zonation scheme: limnetic (0-0.5 ppt), oligohaline (0.5-5 ppt), mesohaline (5-18 ppt), polyhaline (18-30 ppt), and euhaline (>30 ppt)(Anonymous 1959; NOAA 1989).

Biophysical Salinity Zone Integration

The NEI tidal fresh zone (0-0.5 ppt) was considered equivalent to the fresh zone (0.0 ppt) of the biologically-based zonation scheme. Similarly, the 24-marine zone and the NEI seawater zone (>25 ppt) were considered equivalent (Figure 2). Thus, species relative abundance data were directly transferred to the fresh and marine biologically-based zones. NEI mixing zone relative abundance data
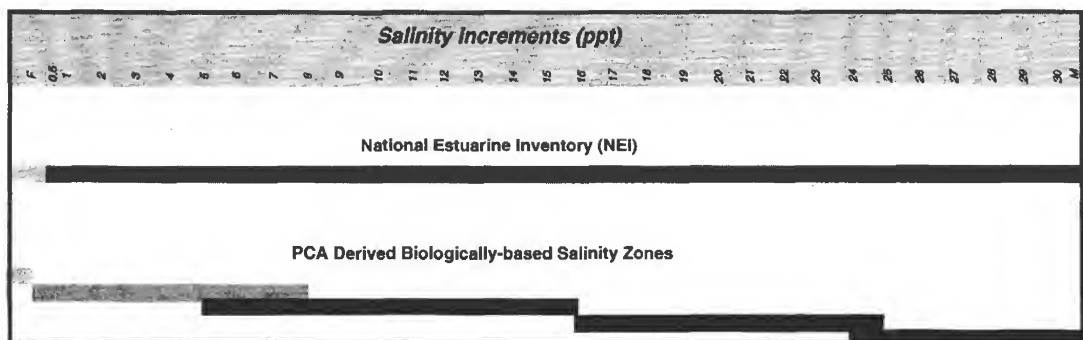

Figure 2. Biologically-based salinity zonation schemes derived from the National Estuarine Inventory (NEI) and Principal Components Analysis (PCA).

encompassed three biologically-based salinity zones (0-8 ppt, 5-16 ppt and 16-25 ppt zones) and were realigned by transferring NEI mixing zone species relative abundance estimates to biological zones based on species habitat associations with the oligohaline, mesohaline and/or polyhaline zones of the Venice system (Figure 3).

ELMR spatial, temporal, and relative abundance data provided information defining species monthly habitat utilization patterns across Gulf of Mexico estuaries. To assess how species distributions may be impacted by increasing or decreasing estuarine salinity habitat, it was necessary to calculate the spatial extent of each salinity zone in each of the 22 estuaries. Relative salinity zone surface areas (km^2) for 5 ppt isohalines in Gulf estuaries were provided by the NOAA Physical Environments Characterization Branch (PECB) (Orlando et al. 1993). To maximize BSI sensitivity to a freshet, isohaline surface

areas were calculated for 20 year averaged "normal" three month low-flow/high-salinity periods. Moreover, this high-salinity period generally represents summer months during which fish diversity is usually at its maximum in Gulf estuaries (Nelson 1992). The 5 ppt isohaline surface areas were then re-aligned to fit biologically-based salinity zones to provide an estimate of salinity zone areas (Table 2). The following alignments were made: BioZone I <0.5 ppt (corresponding to the fresh zone), BioZone II >0.5-8 ppt (corresponding to 0-8 ppt zone), BioZone III 5-15 ppt (corresponding to 5-16 ppt zone), BioZone IV 15-25 ppt (corresponding to 16-25 ppt zone), and BioZone V 25-35 ppt (corresponding to 25-marine zone). To calculate the 0-8 ppt biologically-based zone area, we multiplied the 5-10 ppt zone area by 0.6 (3 of 5 ppt's from the 5-10 ppt zone) and added it to the >0.5-5 ppt zone area to achieve an estimated area proportionate to a >0.5-8 ppt zone. This
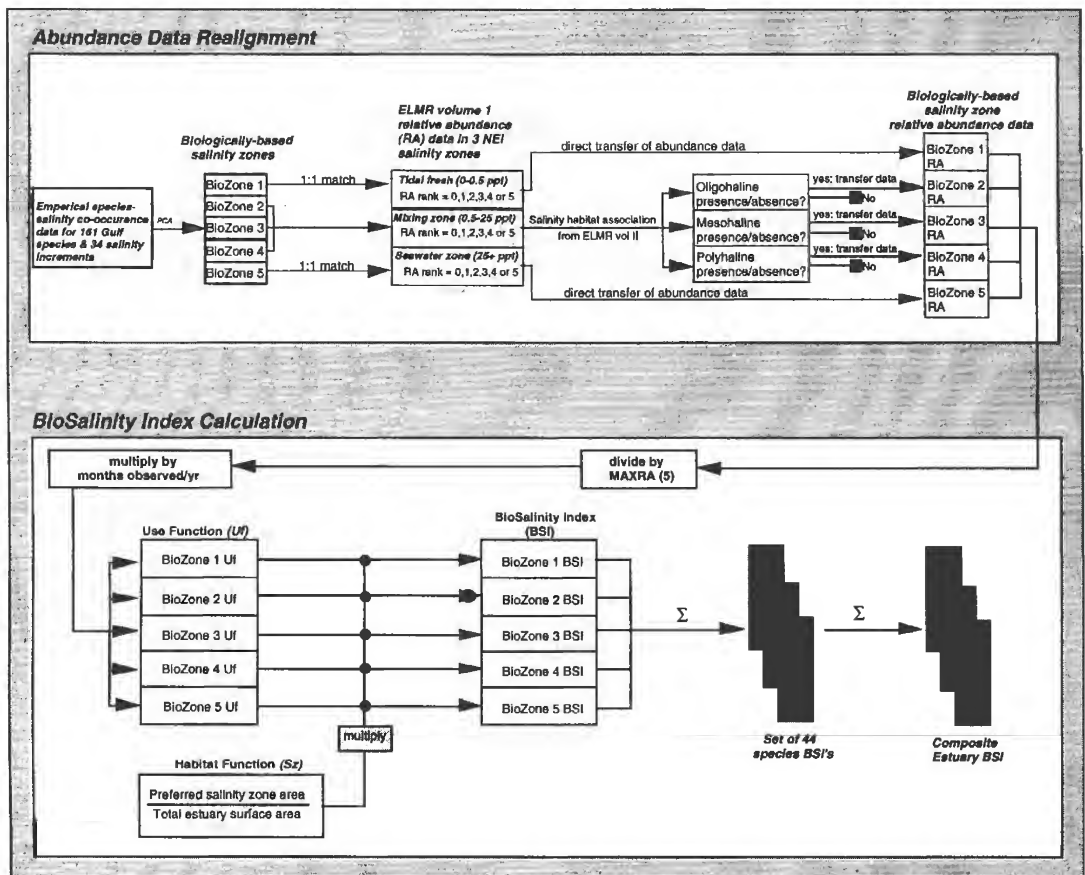

Figure 3. Salinity realignment and BSI calculation framework.

TABLE 2

Biologically-based salinity zone surface areas (km²) during high salinity/low flow periods for Gulf of Mexico estuaries.

Estuary	BioZone I	BioZone II	BioZone III	BioZone IV	BioZone V	Total Area
Tampa Bay	000.00	000.00	000.00	179.43	165.83	*345.26*
Suwannee River	002.81	000.56	003.25	011.18	050.06	*067.86*
Apalachee Bay	000.00	003.86	007.81	016.19	139.89	*167.75*
Apalachicola Bay	000.00	015.17	030.15	071.01	115.65	*231.98*
Choctawhatchee Bay	000.00	000.00	000.68	112.33	016.24	*129.25*
Pensacola Bay	000.00	000.00	004.72	058.85	081.28	*144.85*
Perdido Bay	000.00	000.23	007.12	023.42	007.80	*038.57*
Mobile Bay	000.00	021.74	087.21	176.38	144.44	*429.77*
Mississippi Sound	000.00	002.83	089.63	447.31	330.37	*870.14*
Lake Pontchartrain	000.00	663.53	194.22	000.00	000.00	*857.75*
Breton/Chandeleur Sounds	000.00	000.00	046.73	381.99	078.59	*507.31*
Barataria Bay	086.29	052.40	054.60	149.97	000.00	*343.26*
Terrebonne/Timbalier Bays	000.00	000.00	027.04	325.76	134.71	*487.51*
Lake Calcasieu	000.00	000.00	000.00	009.12	090.20	*099.32*
Sabine Lake	000.00	033.58	094.22	008.09	000.00	*135.89*
Galveston Bay	000.00	024.37	108.96	271.09	182.85	*587.27*
Brazos River	000.00	000.00	000.53	001.75	000.00	*002.28*
Matagorda Bay	000.11	008.57	046.24	272.79	110.36	*438.07*
San Antonio Bay	003.54	018.22	045.24	132.64	026.73	*226.37*
Aransas Bay	000.00	000.00	032.96	099.46	070.39	*202.81*
Corpus Christi Bay	000.00	000.00	000.00	012.50	208.04	*220.54*
Laguna Madre	000.00	000.00	000.00	000.00	506.13	*506.13*

assumes that 1 ppt increments within the 5-10 ppt isohaline are isometric. Table 2 depicts biologically-based salinity zone surface areas for Gulf estuaries included in this study. Figure 3 depicts the pathways used to realign species abundance and distribution data to the biologically-based salinity zones which were subsequently used to calculate BSI values.

BSI Components

Development of this assessment capability was accomplished by integrating empirical species-salinity habitat association data, estuary-specific monthly relative abundance data for Gulf species, and the areal extent of species' preferred salinity zones for the species. This integration permitted simultaneous assessments of species habitat utilization in time and space, resulting in a synoptic measure of habitat utilization termed the Use Function (Uf). The amount of preferred salinity habitat available (Habitat Function) (km²) to each species, coupled with the Use Function, provided the components necessary to calculate the BSI, where RA_{jmax} is the estuary/species specific observed maximum abundance rank which ranges from 0-5. By including U_{fmax} in the equation, we arrive at a product between 0 and 1 which fits the conventional protocol of many biological indices (Monaco 1995).

$$BSI = (U_f / U_{fmax})(Sz).$$
where
$$U_f = (\text{months observed} \cdot \text{yr}^{-1})(RA_{jmax}/5)$$
and
$$Sz = (\text{area of species' preferred habitat} / \text{total estuary area})$$

Species on the low end of the BSI continuum may be highly sensitive to changes in freshwater inflow, and those approaching 1.0 are more tolerant to such changes. Individual salinity zone BSI values were calculated for each species and summed to achieve an estuary/species-specific BSI value for the entire system (Figure 3).

RESULTS

Estuary/Species Level

The BSI is most reliable at the species level. Results of individual species-level BSI values for each estuary are summarized in Figures 4 a and 4 b for adults and juveniles, respectively. These matrices provide a quick and objective means for inter-estuarine comparisons of species sensitivity to changes in freshwater inflow. Because estuarine species often exhibit an ontogenetic shift in habitat requirements and/or preferences, adult and juvenile life stages were treated independently. Analysis of variance (ANOVA)
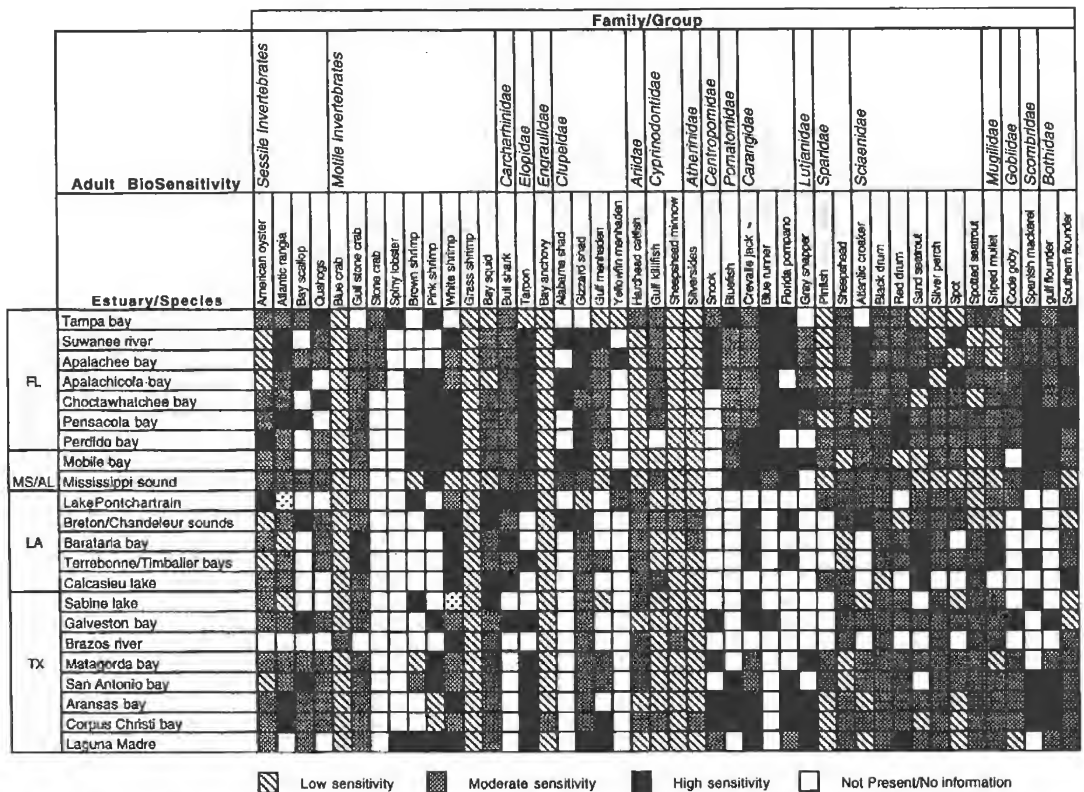
Figure 4a. Adult estuary-specific categorical BSI ranks (high sensitivity ≤ 0.33, moderate sensitivity = 0.34 - 0.66, and low sensitivity ≥ 0.67).

indicated a significant difference in mean BSI values between these two life stages (P<0.001), with adults consistently exhibiting lower BSI values (higher sensitivity) than their juvenile counterparts. Species/estuary-specific BSI values were assigned to categorical ranks based on their relative sensitivity to a significant change in salinity. Categorical rank boundaries were chosen to partition the results into thirds. The boundaries are defined as: high sensitivity (≤ 0.33), moderate sensitivity (0.34 - 0.66), and low sensitivity (≥ 0.67). These limits do not represent a critical value which is statistically unique from the other. Rather they provide a reasonable means of categorizing salinity sensitivity.

A total of 968 possible species/estuary combinations exist for each life history stage, of which 18.8% (N=182) for adults and 16.6% (N=151) for juveniles exhibited a high potential sensitivity to changes in freshwater inflow. Thirty-six percent (N=348) of adults exhibited moderate sensitivity and 20.2% (N=196) low sensitivity, while 38.5% (N=372) and 28% (N=271) of juveniles exhibited moderate and low BSI values, respectively. The remaining cases were either not present, or reliable sources of information pertaining to their abundance and distribution were not found.

Individual BSI values for all estuary/species/life stage combinations were then broken down into their two components (use function and habitat function) to isolate the component which exacted the greatest influence on individual BSI values. These two components are plotted in Figure 5 for all estuary/species/life stage cases (N=1936). Those species (cases) which are least sensitive to changes in salinity structure reside in quadrant I of Figure 5. These are species which are generally found in high numbers throughout the year and tolerate a wide range in salinities. Cases residing in this quadrant are classic estuarine species such as Engraulids (anchovies) and Atherinids (silversides). The majority (60%) of Gulf estuary/species/life history stage combinations reside in quadrant III. These are cases whose species have ample preferred habitat in their respective estuaries. However, their usage of, and distribution in that habitat might be limited by other physical and biological constraints (i.e., seasonality and predation risk, etc.). Cases which fall in quadrant III also
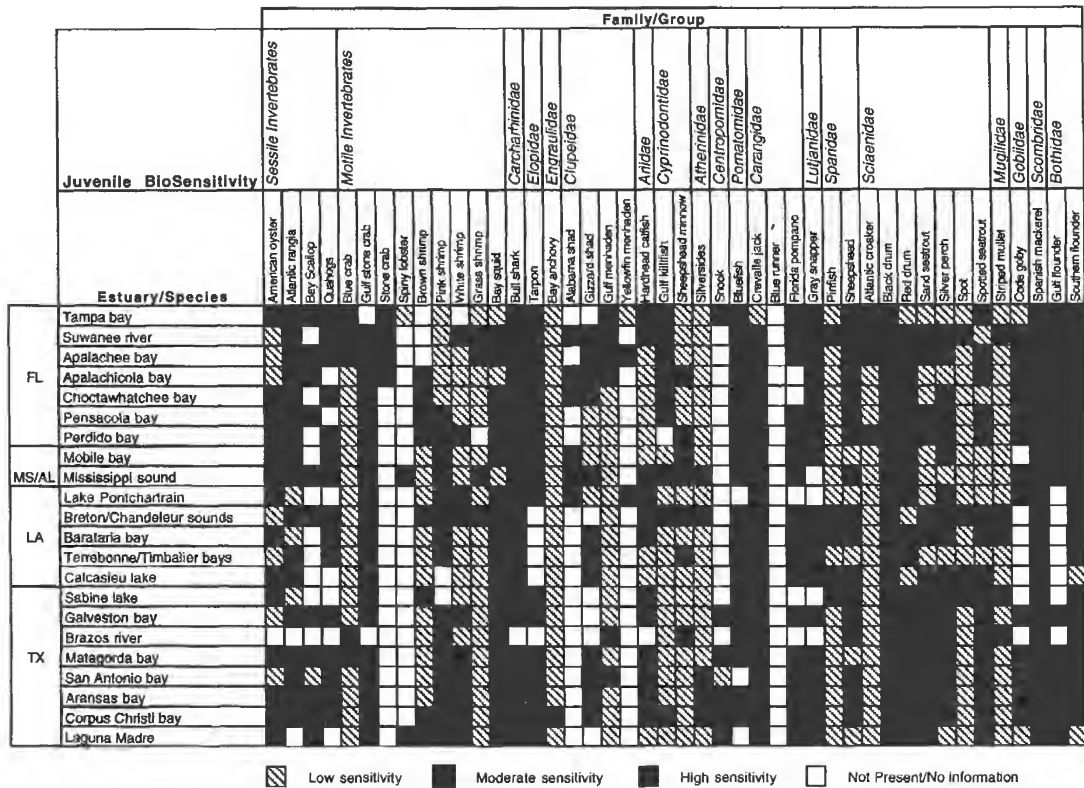
Figure 4b. Juvenile estuary-specific categorical BSI ranks (high sensitivity ≤ 0.33, moderate sensitivity = 0.34 - 0.66, and low sensitivity ≥ 0.67).

may be species whose salinity tolerance may be as broad as those residing in quadrant I, but whose relative abundance is lower.

Species residing in quadrants II and IV are those that may be most susceptible to change via altered salinity structure. As such, these species may be amenable to management via freshwater inflow regulation into their respective estuarine systems. Atlantic rangia (*R. cuneata*) is unique to quadrant II, while a number of species reside in quadrant IV. Species in quadrant IV represent species which can be placed into four major taxonomic groupings. These include sessile invertebrates (e.g., Eastern oyster and scallops), Clupeids with an affinity for fresher waters (e.g., Alabama and gizzard shads), predominately marine species (e.g., blue runner and Gulf flounder), and motile invertebrates which are generally restricted to Floridean waters (e.g., spiny lobster). It is important to note that many of the species in quadrant IV reside there because of extremely low abundances relative to other more abundant Gulf estuarine species. Nevertheless, the composite BSI values and component "quad plots" provide managers with

simple and objective tools to assess potential impacts of salinity habitat alterations on fishes and invertebrates.

Composite Estuary BSI

Species BSI values can be averaged for an estuary to provide a composite estuary-level BSI value (Figure 3). This composite value provides coastal resource managers with a vehicle for regional strategic assessments of differences in biological sensitivity to salinity changes across estuaries. The upper histogram in Figure 6 represents estuarine composite BSI values based on the 44 ELMR species and enables comparative analysis of estuaries across the Gulf. For example, these results indicate that the average Mississippi Sound species assemblage (std.dev≈ 0.2) is less sensitive to salinity changes than the Perdido Bay assemblage. This may be attributed to either a difference in community structure or to a difference in the availability and homogeneity of preferred salinity habitat for each of the representative species. A change in either of these factors has the potential to significantly
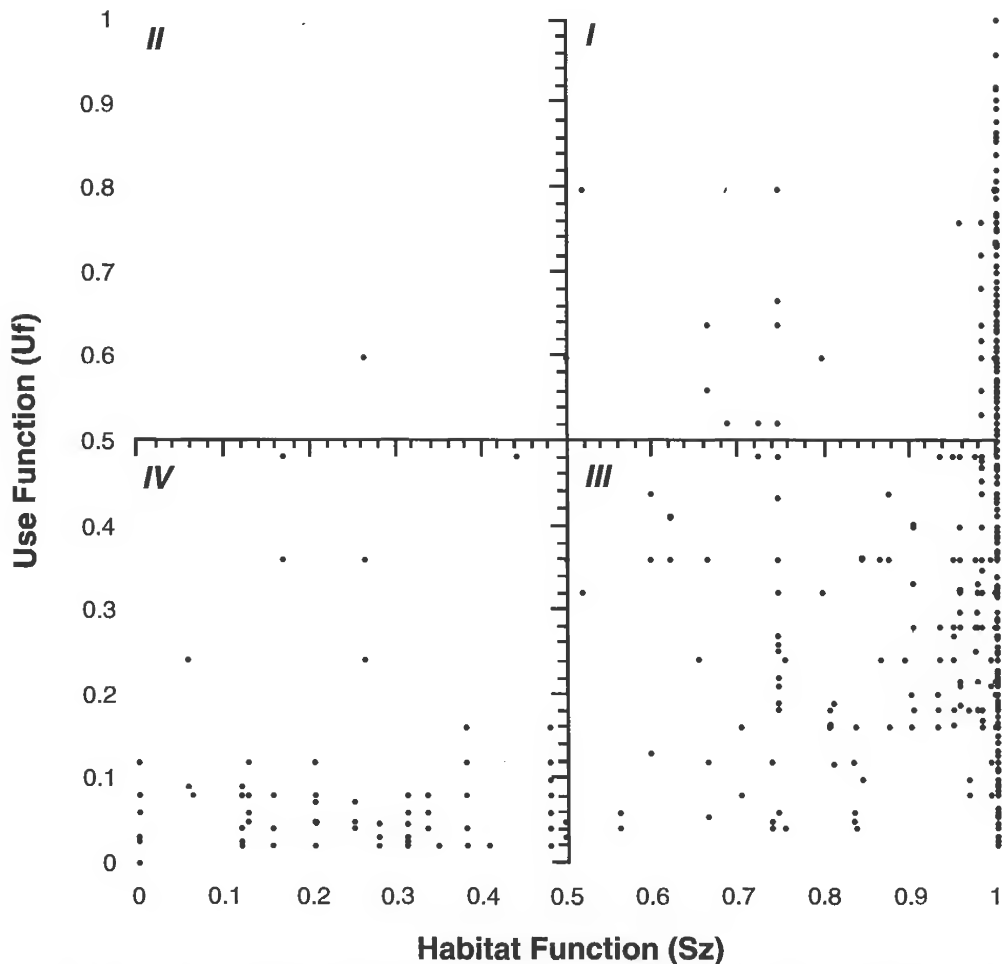
Figure 5. Quadrant plot of BSI component (use function and habitat function) values for all estuary/species/life history stage cases in Gulf of Mexico estuaries.

alter estuary composite BSI values. For this reason, natural resource managers must proceed with caution when interpreting composite BSI values. In an effort to evaluate economically important species that represent the geographical extent of the northern Gulf of Mexico, participants in the EPA freshwater inflow workshop identified five "indicator" species to analyze (NOAA 1995). The mean BSI values for the five species (brown shrimp, pink shrimp, white shrimp, American oyster, and spotted seatrout) are shown in the upper histogram of Figure 6. Mean BSI histograms were markedly different between the five and 44-species assemblages, with the former exhibiting greater variability across estuaries (Figure 6). However, the indicator species revealed similar trends

in salinity sensitivity across Gulf estuaries when compared to the 44-species assemblage results (SEA 1995). These results suggest that factors other than salinity may have a greater influence over the abundance and distribution of the 44 ELMR species. The relatively low proportion of species exhibiting high sensitivity to changing freshwater inflow can be attributed in part to the fact that most of the 44 Gulf species in this study are estuarine dependent and are characterized by a variety of physiological and behavioral adaptations for life in estuarine waters. The degree of change in community structure would, in large part, be dictated by which salinity zones were affected, the magnitude of that change, and the initial composition of the estuarine assemblage. Estuaries which are
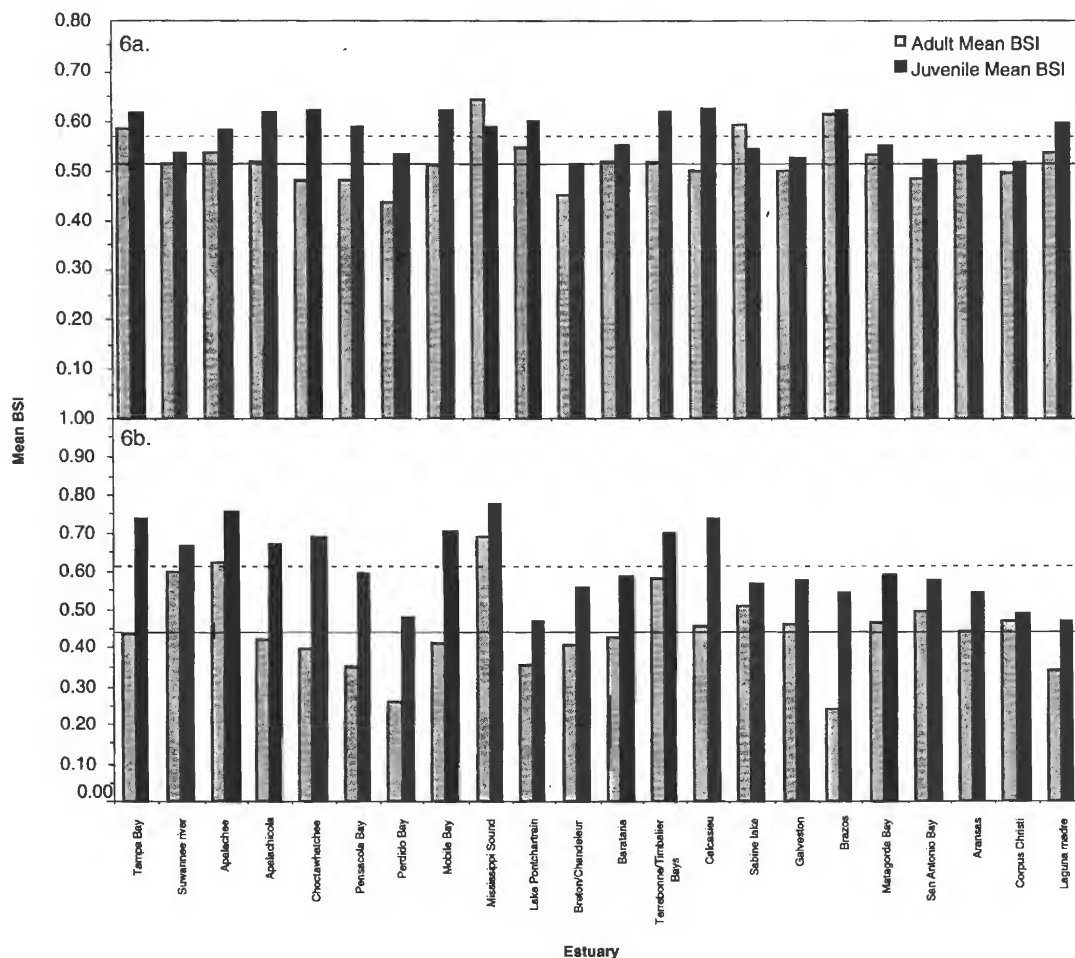
Figures 6a. Adult and juvenile mean BSI values for 44 ELMR species assemblages. Dashed line represents the assemblage-wide juvenile mean BSI. Full line represents assemblage-wide adult mean BSI. 6b. Adult and juvenile mean BSI values for five indicator species assemblages. Dashed line represents the assemblage-wide juvenile mean BSI. Full line represents assemblage-wide adult mean BSI.

frequented by marine and/or freshwater species would undoubtedly exhibit lower composite BSI ranks than the average estuary. Increasing the number of species included in this analysis would provide more insight into the sensitivity of the BSI to the presence of such species.

DISCUSSION

Because the BSI incorporates individual species habitat preferences in time and space, those species which are thought of as "classically estuarine" exhibit highest BSI values. These species generally exhibit euryhalinity and often are one of the more numerically dominant species in

a system. Moreover, elevated BSI values for these species may be due to the fact that these species spend the majority, if not all, of their lives, in estuarine waters. In addition, although the BSI does not include measures of ecological interaction (i.e., predator-prey oscillations, recruitment, competition, etc.), it is assumed that this type of information is builtin to the index by incorporating empirical monthly species relative abundance and distribution data for Gulf estuaries. We assume these data represent ecological interactions and their influence on the abundance and distribution of Gulf species. Management of these species by freshwater inflow regulation should be complemented by other measures of ecological interaction and improvement to

habitat. Depending on the management objectives, use and interpretation of the index can differ when comparing species-level BSI relative to assemblage-level BSI.

Our ultimate intent in developing the BioSalinity Index was to establish a quantitative method to rank Gulf estuaries according to their relative biological sensitivity to changes in freshwater inflow. In this study, sensitivity was defined as a the potential for species and subsequent assemblages to exhibit a change in total available habitat utilization in response to significant alterations in estuarine salinity structure. For example, if a species exclusively uses the freshwater zone within an estuary, its population may exhibit a decline in reproductive or competitive fitness if this zone decreased in size. As coastal zone managers learn more about local and regional estuarine salinity character and dynamics, the BSI will provide a valuable, objective tool to assess and predict potential changes in species populations and estuarine community structure resulting from a measurable change in salinity structure.

ACKNOWLEDGMENTS

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Benthic-Pelagic Coupling in Northern Gulf of Mexico Estuaries: Do Benthos Feed Directly on Phytoplankton?

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BENTHIC-PELAGIC COUPLING IN NORTHERN GULF OF MEXICO ESTUARIES: DO BENTHOS FEED DIRECTLY ON PHYTOPLANKTON?

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ABSTRACT Few of the dominant benthic taxa of the northern Gulf of Mexico feed directly on phytoplankton. Rather, most of them feed on near-bottom seston and detritus. This is in contrast to models for Chesapeake Bay and San Francisco Bay. We found that detritivores represented over 80% of the macrobenthic organisms and over 90% of the biomass in Gulf of Mexico estuaries. The paucity of benthos that consumed phytoplankton led us to hypothesize that macrobenthos in Gulf of Mexico estuaries had less effect on plankton communities than was documented in U.S. east coast and west coast estuaries, where benthic communities consumed much of the water-column production. We provided as evidence gut-contents analyses of dominant taxa, the feeding morphology of suspension feeders (especially clams), and the lack of vertical mixing or strong turbulent flow that is necessary for benthos to remove substantial portions of the phytoplankton.

INTRODUCTION

Recent investigations into estuarine trophic ecology established that benthic organisms in San Francisco Bay (Cloern 1982, Alpine and Cloern 1992) and Chesapeake Bay (Cohen et al. 1984, Gerritsen et al. 1994) may play a major role in maintaining water clarity. Dominant benthos of those estuaries feed directly on phytoplankton (water-column production) and may clear the water of certain planktonic organisms. In contrast, it is widely held that few suspension-feeding benthos of northern Gulf of Mexico estuaries feed directly on phytoplankton; rather, most of them are thought to ingest suspended organic matter (seston) from near the sediment-water interface or detritus on the sediment surface (Darnell 1961, Day et al. 1989, D'Avanzo and Valiela 1990, Gaston et al. 1995).

The purpose of our research was to determine whether dominant benthos of the northern Gulf of Mexico feed directly on phytoplankton. Before we could address the problem we had to answer several questions. Which benthos were numerical dominants? Which benthos were biomass dominants? How did these dominant species feed? Our results allowed us to determine whether trophic models proposed for Chesapeake Bay were applicable to Gulf of Mexico estuaries.

MATERIALS AND METHODS

Sampling and Analyses

Benthic samples were collected from 201 estuarine stations (603 samples) from Anclote Anchorage, Florida to the Rio Grande River, Texas during July – August of 1991 (100 stations) and 1992 (101 different stations) under the auspices of the Environmental Protection Agency (EPA)

Environmental Monitoring and Assessment Program (EMAP). A surface-area based, probabilistic sampling design was used to ensure that all estuaries were equitably sampled and represented (Summers et al. 1992, Engle et al. 1994).

Loran-C was used to locate sampling stations before water-quality parameters were measured and quantitative benthic macroinvertebrate samples were collected (see methods in Heitmuller and Valente 1991, Summers et al. 1992). Three (3) replicate macrobenthic samples were collected with a modified Van Veen grab (413 cm^2). Samples were washed on a 500-um screen, transferred to bottles containing 10% buffered formalin and Rose Bengal as a vital stain.

Wet-weight and dry-weight biomass were determined by methods described in Gaston et al. (1996). Biomass values included only soft tissues. Molluscs were weighed without shells, tube-dwelling taxa without tubes, and encrusting taxa were scraped from their hosts.

Organisms were identified to the lowest practical taxon and enumerated. Quality checks of identifications and counts were conducted by senior project taxonomists, and greater than 10% error resulted in reanalysis of samples. Complete descriptions of methods and quality assurance procedures used in this program are available in Heitmuller and Valente (1991) and Summers et al. (1992).

Dominant Species

We used EMAP data and Gaston et al. (1995) for benthic biomass and abundance values in the study area. *Crassostrea virginica* (commercial oysters) biomass values were estimated from Eleuterius (1977), Louisiana Department of Wildlife and Fisheries information (unpublished data), Weston and Gaston (1982), and EMAP data.

Gut-contents Analyses of Fresh Specimens

We collected live specimens of *Rangia cuneata* (common brackish-water clam) in Mississippi Sound at a subtidal site along East Beach Drive in Ocean Springs (Jackson Co., MS) and Back Bay near the old Biloxi Hospital (Harrison Co., MS) during June 1995. Specimens were collected by hand, transported to the laboratory on ice, then dissected for gut-contents analyses. Twenty-eight specimens of various sizes (20mm - 45mm) were dissected. Ingested material was removed from the siphon area (primarily pseudofeces) and foregut. We used compound and scanning-electron microscopes to identify and determine the likely sources of ingested material. Gut contents were compared with dominant organisms in water samples (20-liter containers filled with near-bottom water) taken during *R. cuneata* collections.

Macrobenthic Trophic Group Assignments

Benthic organisms were assigned trophic groups based on feeding behavior and food type. Trophic groups used in this study were surface-deposit feeders (SDF), subsurface-deposit feeders (SSDF), suspension and filter feeders (FF), carnivores (CARN), omnivores (OMNI), and others (XXX) (sensu Gaston et al. 1995). Thus, taxa that fed directly on phytoplankton were classified as suspension feeders. Trophic group assignments were based on morphological and behavioral characteristics of estuarine macrobenthos supported by peer-reviewed scientific literature, unpublished observations, and personal expertise of the authors.

Data Analysis

Macrobenthic abundance data from 201 stations were used to estimate relative proportions of each trophic group found in estuaries of the northern Gulf of Mexico. This analysis was completed using data from stations for 1991 and 1992 combined, as well as for each sampling year independently. Densities were mean numbers of individuals (m^{-2}) among all stations sampled. Biomass was calculated as mean biomass (m^{-2}) among all stations.

RESULTS

Suspension feeders composed the largest portion (67.5% of biomass) of the benthos in northern Gulf of Mexico estuaries (Table 1, Figure 1), and suspension-feeding bivalve molluscs had the greatest biomass among the dominants (49.7% of total dry-weight benthic biomass) (Table 2). Two bivalves contributed the most biomass,

Rangia cuneata (19.3% of total biomass; mean biomass, 1.37 g m^{-2}), and *Crassostrea virginica* (approximately 20% of total biomass; approximately 1.2 g m^{-2}) (Table 2). *Mulinia lateralis*, an abundant clam in many Gulf of Mexico estuaries, totaled only 0.44% of the biomass. Benthic trophic groups other than suspension feeders, including all deposit feeders, omnivores, and carnivores, totaled only 32.5% of the biomass (Table 1).

Abundance data were based on approximately 70,890 benthic organisms (840 taxa; mean density, 2846.4 organisms m^{-2}) from 201 stations (603 samples). The only species that occurred in abundance and contributed substantially in biomass was *Rangia cuneata* (mean biomass, 1.37 g m^{-2}; mean density, 35 m^{-2}) (Table 2). The other abundant benthic organisms were small bodied and did not contribute significantly to total biomass as single species: *Mediomastus californiensis*, *Corophium cf. lacustre* (surface deposit-feeding amphipod; mean density, 178 m^2), *Mulinia lateralis*, *Probythinella louisianae*, *Streblospio benedicti*, *Texadina sphinctostoma*, and several species of tubificid oligochaetes (Table 2).

Nearly equal proportions (25 - 30%) of the three categories of detritivores (FF, SDF, and SSDF) accounted for approximately 85% of the macrobenthic fauna in northern Gulf of Mexico estuaries (Figure 1). Carnivores (CARN), especially nemerteans, represented approximately 12% of total macrobenthic abundance, while omnivores (OMNI) and others (XXX) each accounted for less than 4% of total macrobenthic abundance.

Rangia cuneata gut contents included few planktonic organisms. Rather, ingested material was dominated by sand, silt, and clay particles (> 90%), a few benthic diatoms, frustules of dead diatoms, and bits of plant matter (Figure 2). There were many sand grains, much detritus, but few whole organisms. None of the dominant taxa observed in the plankton samples (minute navicular diatoms, centric diatoms, and calanoid copepods) were observed in the ingested material.

DISCUSSION

Benthos that dominated northern Gulf of Mexico estuaries included few large, deep-burrowing suspension feeders that typify large estuaries of the United States east coast (Schaffner et al. 1987, Diaz and Schaffner 1990), a major distinction in trophic status of the two regions (Gaston et al. 1995). Gulf of Mexico estuaries generally lack dense populations of large clams, such as *Mercenaria mercenaria*, perhaps because these estuaries lack the tidal energy required for turbulent flow near the sediment-water interface. Gerritsen et al. (1994) discussed the importance of such energy to the feeding of large bivalves in Chesapeake Bay.

TABLE 1

Benthic community trophic structure for northern Gulf of Mexico estuaries. Data collected at 201 randomly selected stations (603 samples).

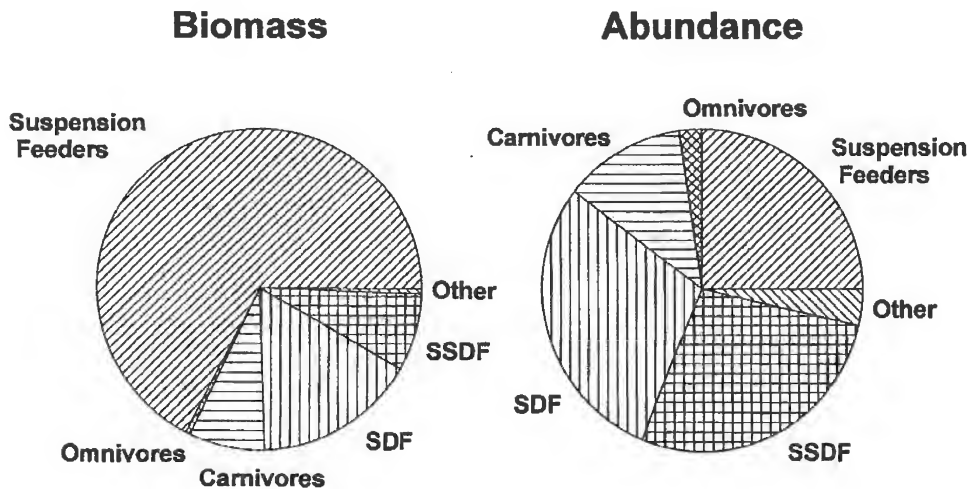| Trophic Group	Biomass (g m^{-2}) (percentage of total)	Mean number of organisms (m^{-2}) (percentage of total)
Suspension Feeders	4.76 (67.5)	712.7 (25.0)
Surface Deposit Feeders	1.14 (16.2)	833.2 (29.3)
Subsurface Deposit Feeders	0.55 (7.8)	782.5 (27.5)
Carnivores	0.53 (7.5)	349.9 (12.3)
Omnivores	0.04 (0.5)	63.2 (2.2)
Other	0.04 (0.5)	104.9 (3.7)
TOTALS	7.06 (100)	2846.4 (100)

Biomass

Abundance

Figure 1. Benthic trophic structure of northern Gulf of Mexico estuaries, by biomass and by abundance. Proportions are percentage values.

TABLE 2

Dominant benthic taxa (1991-1992). Data for 201 randomly selected stations in northern Gulf of Mexico estuaries. Values are dry-weight biomass. Species with low density values were grouped as higher taxa for brevity.

| Taxa	Trophic Group	Biomass(g m⁻²)	Density(m⁻²)
Rangia cuneata (Bivalvia)	FF	1.37	35
Mulinia lateralis (Bivalvia)	FF	0.03	129
Other Bivalves*	SDF	0.70	<5
	FF	1.42	<9
Probythinella louisianae (Gastropoda)	SDF	< 0.10	109
Texadina sphinctostoma (Gastropoda)	SDF	< 0.10	79
Caecum johnsoni (Gastropoda)	OMNI	< 0.10	47
Mediomastus californiensis (Annelida)	SSDF	< 0.20	386
Streblospio benedicti (Annelida)	SDF/FF	< 0.01	85
Paraprionospio pinnata (Annelida)	SDF/FF	< 0.01	58
Spiochaetopterus costarum (Annelida)	FF	< 0.01	54
Amphipoda	SDF	< 0.10	230
Tubificidae	SSDF	< 0.10	110
Nemertea	CARN	0.05	105

* includes *Crassostrea virginica* (commercial oysters)
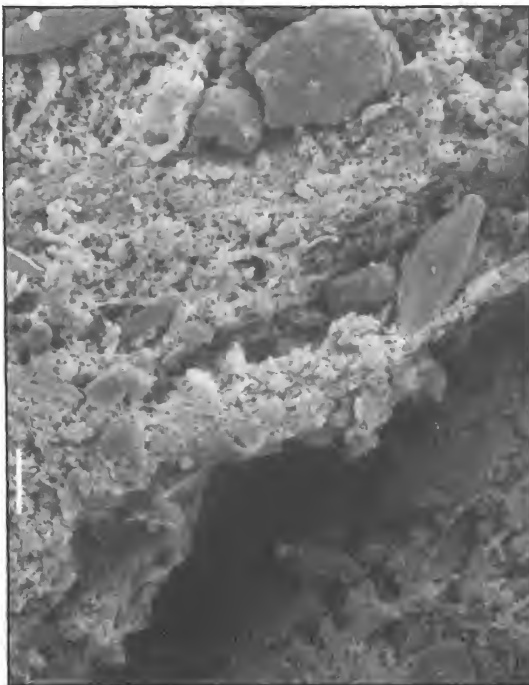
Figure 2. Scanning electron micrograph of Rangia cuneata gut contents. *R. cuneata* specimens were collected in Mississippi Sound (Harrison and Jackson Co., MS) during 1995. Particles of sand, silt, clay are evident, as are a few diatoms. Scale = 10 microns.

The only large suspension feeders of Gulf of Mexico estuaries that represented enough biomass to potentially affect phytoplankton production were *Rangia cuneata* and *Crassostrea virginica*. Do these species feed directly on phytoplankton? It appears unlikely that phytoplankton are a major portion of their diets. These two species lack the long siphons that characterize bivalves of other estuaries (e.g., *Mya arenaria*, *Tagelus plebius*), leaving them to feed in the benthic boundary layer (an area of reduced turbulence) near the sediment-water interface (see Muschenheim and Newell 1992). Although benthos can remove substantial amounts of phytoplankton in shallow systems with strong turbulent flow (Newell 1988, Sornin et al. 1990, Sullivan et al. 1991, Ulanowicz and Tuttle 1992), oysters in Gulf of Mexico estuaries feed primarily on near-bottom seston and detritus (Galtsoff 1964, Soniat et al. 1984, Soniat and Ray 1985) and to a lesser extent on phytoplankton (Stickney 1984). Without the regular (tidal) mixing energy to expose oysters to upper water-column phytoplankton, Gulf of Mexico oysters could not have an estuarine-wide effect on phytoplankton biomass.

Rangia cuneata are widely distributed in oligohaline habitats of Gulf of Mexico estuaries, and are known to be nonselective suspension feeders (Olsen 1976, Harrel and McConnell 1995) that depend on the presence of organic

matter for larval settlement and survival (Sundberg and Kennedy 1993). *R. cuneata* gut-contents analyses confirmed that these clams feed on detritus and/or seston of the benthic boundary layer, rather than on phytoplankton directly.

We recognize that chlorophyll a in the water column results from both phytoplankton (water-column production) and resuspended benthic microalgae (Christensen and Kanneworff 1985, Day et al. 1989, Baines and Pace 1991, Graf 1992). Biomass of resuspended benthic diatoms may exceed that of phytoplankton in some estuaries (Baillie and Welsh 1980, de Jonge and van Beusekom 1992), and may provide the major diet of bivalves (Muschenheim and Newell 1992). Similarly, vascular plants (seagrasses and marsh vegetation) provide substantial detritus in some habitats (Heffernan and Gibson 1983, Fry 1984, Shaffer and Sullivan 1988). These observations and our analyses lead us to the conclusion that food ingested by bivalves in Gulf of Mexico estuaries likely originated from a variety of sources, but consisted mostly of seston and detritus. Of course, seston and detritus may include suspended benthic microalgae and suspended or sedimented phytoplankton. Therefore, it is inappropriate to assume that either *R. cuneata* or *C. virginica* feed exclusively on phytoplankton.

Although few of the dominant taxa in northern Gulf of Mexico estuaries feed directly on phytoplankton, certainly some benthos may ingest phytoplankton selectively. These may include taxa capable of feeding above the sediment-water interface in the water column, such as barnacles and bryozoa (attached to structure), benthos attached to seagrass blades, and mussels attached to structure or in shallow water. Yet, these taxa represent a small portion of the biomass in Gulf of Mexico estuaries, and would affect limited areas with little impact overall on the estuary.

We suggest that the models proposed for benthos of Chesapeake Bay, in which bivalves effectively removed over 50% of the annual primary production in some regions (Gerritsen et al. 1994), do not apply to Gulf of Mexico estuaries. We also suggest that additional oyster stocking, as proposed for improved water clarity in Chesapeake Bay (Ulanowicz and Tuttle 1992), would have little effect on overall water clarity in Gulf of Mexico estuaries. Gulf of Mexico estuaries are relatively shallow with small tidal amplitude. As a result, oyster distribution in Gulf of Mexico estuaries is confined to relatively narrow habitats, which limits potential for stocking effects. Furthermore,

water clarity problems in Gulf of Mexico estuaries cannot be solved simply. Turbidity is related to environmental variables such as erosion and sediment transport, bioturbation, enhanced deposition of particulates by feeding of benthos, presence and density of seagrasses, and sediment stabilization by benthic algae or tube-dwelling taxa (Stickney 1984, Day et al. 1989, Diaz and Schaffner 1990). Wind-driven tides regularly exceed lunar tides and may account for many variations in water clarity (Stickney 1984). Human-related factors affect turbidity in Gulf of Mexico estuaries as well, including shrimp trawling (de Groot 1984, Gaston 1990, Hutchings 1990, Riemann and Hoffmann 1991), shell dredging (Tarver 1972, Tarver and Dugas 1973, Francis et al. 1994), and secondary effects of urban runoff, sewage discharge, and other human activities (Stickney 1984).

Our understanding of the fundamental conception of trophic exchange in estuaries changed during the past few years. Scientists once believed that vascular plant biomass was the key to understanding estuarine productivity, but evidence showed that benthic and planktonic algae played a major role in many systems (Haines 1979, Fry 1984). Today there is a temptation to assume that benthic suspension feeders depend entirely on phytoplankton, based on evidence in San Francisco Bay (Cloern 1982, Alpine and Cloern 1992) and Chesapeake Bay (Cohen et al. 1984, Gerritsen et al. 1994). We suggest that such a premise is unfounded in Gulf of Mexico estuaries, where relatively few taxa feed directly on phytoplankton, and detritus-based trophic ecosystems depend primarily on near-bottom seston and detritus.

ACKNOWLEDGMENTS

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Early Growth in Weight of Kemp's Ridley Sea Turtles (*Lepidochelys kempii*) in Captivity

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EARLY GROWTH IN WEIGHT OF KEMP'S RIDLEY SEA TURTLES (*LEPIDOCHELYS KEMPII*) IN CAPTIVITY

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ABSTRACT Growth in individual weight (w, kg) of Kemp's ridley sea turtles (*Lepidochelys kempii*) in captivity was described for 15 year-classes (1978-1992) of turtles between ages (t) 0.17 to 1.22 yr, using *ln*-linear regression: $lnw = lnc + dt^{1/2}$, where lnc is the intercept and d is the slope (growth rate index). There was significant ($P < 0.001$) heterogeneity in d among year-classes, with slowest growth (d = 3.798) exhibited by the 1983 year-class and fastest growth (d = 6.929) by the 1985 year-class, but there was no significant trend in d ($P = 0.307$) over year-classes. The variance of residuals from regression, s^2_{reg}, ranged from 0.2032 for the 1978 year-class to 0.0075 for the 1992 year-class, and showed a significant ($P = 0.0001$) logarithmic decrease over the year-classes. This decline in variation among individuals was probably due to a a shift toward sex ratios dominated by one sex (females), improvements in rearing facilities, year-around control of seawater temperature which reduced disease incidence, improved diet, and reduced feeding levels. The relationship between w and scl (straight carapace length) was also described.

INTRODUCTION

The Kemp's ridley (*Lepidochelys kempii*) head-start experiment was initiated in 1978 as part of a Mexico-U.S. recovery program for this seriously endangered species (Klima and McVey 1982; Woody 1986, 1989). Its main purposes were to increase survival by captive-rearing the turtles during the critical first year of life, and to establish a nesting colony on Padre Island, Texas (Figure 1) through imprinting (Klima and McVey 1982; Woody 1986, 1989; Shaver 1989, 1990). Secondarily, it offered opportunities to develop husbandry practices (Fontaine et al. 1985, 1989; Leong et al. 1989), and to study growth and survival in captivity and in the Gulf of Mexico, following reintroduction (Caillouet and Koi 1985; Caillouet et al. 1986, 1989, 1993, 1995a, b, c).

Of the 25,676 hatchlings received alive from the 1978-1992 year-classes, 22,255 (86.7%) were successfully reared, tagged and released into the Gulf of Mexico at sizes comparable to late-pelagic or early post-pelagic stage in wild Kemp's ridleys (Ogren 1989). Captive-rearing ended with release of the 1992 year-class, but the search for head-started Kemp's ridleys in the wild continued (Byles 1993; Williams 1993; Eckert et al. 1994). In May 1996, the first two documented nestings by head-started Kemp's ridleys occurred at Padre Island (Shaver 1996). One nester was from the 1983 year-class and the other from the 1986 year-class.

This paper describes and summarizes growth of the 1978-1992 year-classes of Kemp's ridleys in captivity up to 1.22 yr of age, based on an exponential model.

MATERIALS AND METHODS

Hatchlings were obtained from eggs collected at the species' primary nesting beach near Rancho Nuevo, Tamaulipas, Mexico (Figure 1; Caillouet 1995b). Most hatchlings came from eggs placed in incubation boxes containing sand from the National Park Service's Padre Island National Seashore (PINS) near Corpus Christi, Texas (Figure 1), and transported to PINS for incubation, hatching and "imprinting" (Burchfield and Foley 1989; Shaver 1989, 1990). However, some were "imprinted" at Rancho Nuevo, after they emerged from eggs placed in artificially constructed nests within protected corrals (Caillouet 1995b). Hatchlings from PINS or Rancho Nuevo were transferred to the National Marine Fisheries Service's Galveston Laboratory for captive-rearing.

Individual weights (w, kg) were measured on samples of turtles at varying intervals during captive-rearing of year-classes 1978-1992, so that feeding rate could be controlled as a percentage of average body weight (Fontaine et al. 1985, 1989; Caillouet et al. 1986, 1989). Straight carapace lengths (scl, cm) were measured less frequently (Fontaine et al. 1985, 1989). Sample size for w at age (t, yr) varied from 1 to 1,774 turtles.

We calculated the variance, s^2, and mean, $\overline{w}$, of all samples containing 25 or more turtles. The slope of the linear regression of lns^2 on $ln\overline{w}$ was 2.014 for turtles 0.17-1.22 yr (2-14.6 mo) old, suggesting that the distribution of w at t was *ln*-normal within that range of t (Figure 2; see Taylor 1961). Turtles less than 0.17 yr old were excluded in fitting the linear regression, because the scatter of points

Figure 1. Location of the National Marine Fisheries Service (NMFS) Galveston Laboratory, National Park Service (NPS) Padre Island National Seashore and Rancho Nuevo nesting beach.
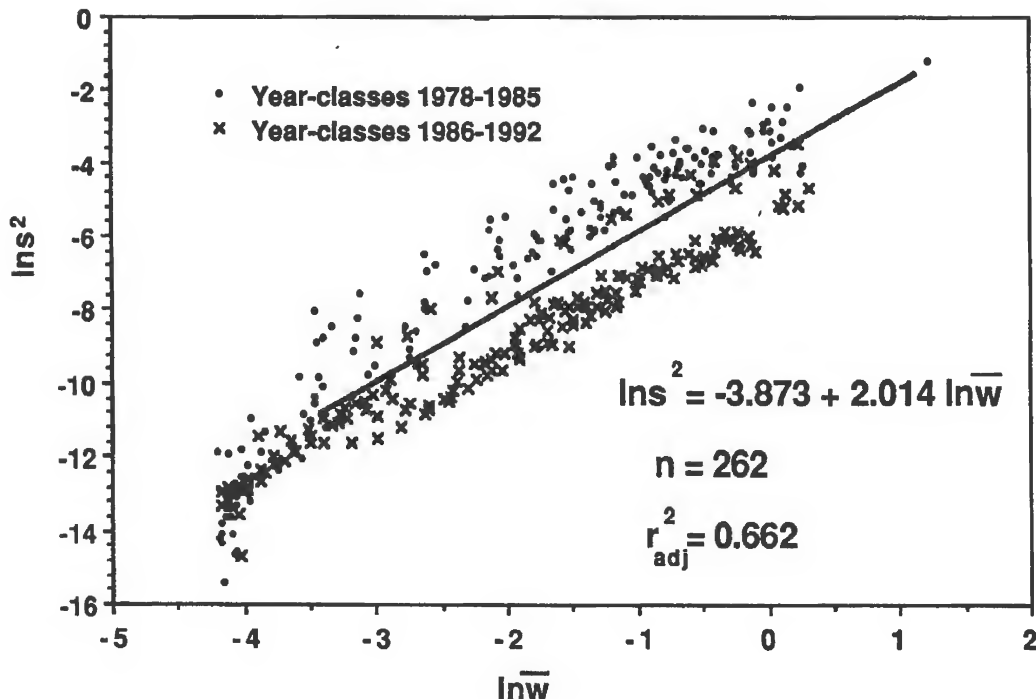
Figure 2. Relationship between natural logarithms of variances and arithmetic means (lns^2 and $ln\overline{w}$, respectively) of weight (w, kg) in samples of captive-reared Kemp's ridleys (*Lepidochelys kempii*) containing 25 or more turtles at age t. The straight line was fitted to 262 data points representing turtles 0.17 to 1.22 yr of age, but the scatter also included 86 data points for turtles < 0.17 yr old.

curved downward in the left portion of the lns^2 vs $ln\overline{w}$ plot (Figure 2). We plotted the data based on two groups of year-classes, with dots representing the 1978-1985 year-classes and x's representing the 1986-1992 year-classes. The latter year-classes were an estimated 83.0-99.6% female, whereas the former were 28.8-53.8% female, except for year-class 1981 in which the inadequate sample of four turtles contained only females (Caillouet 1995a).

Growth of turtles, between ages 0.17 and 1.22 yr, in each year-class and for combined year-classes, was described by an exponential model fitted by *ln*-linear regression (see Caillouet et al. 1986, 1989), as follows:

$$lnw = lnc + dt^{1/2} \qquad (1)$$

where
  *ln*c = intercept, and
  d = slope (growth rate index)

In addition to the *ln*-transformation of w, a square root transformation of t was necessary to linearize the relationship (see Box and Tidwell 1962; Caillouet et al. 1986, 1989).

The *ln*-linear relationship between w and scl was determined for combined year-classes, as:

$$lnw = lna + b \, lnscl \qquad (2)$$

where
  *ln*a = intercept, and
  b = slope

Data from turtles 0.01 yr ≤ t ≤ 1.22 yr were used in fitting equation 2.

Goodness of fit for all *ln*-linear regressions was measured by the adjusted coefficient of determination, r^2_{adj}, calculated as follows:

$$r^2_{adj} = 1 - [(n - 1)(1 - r^2)/(n - 2)]$$

where
  n = number of observations
  r^2 = coefficient of determination

Estimates of *ln*w obtained from equation 1 were detransformed to w_{adj}, which is the estimated w adjusted for *ln*-normal bias (see Sprugel 1983) as follows:

$$w_{adj} = EXP [lnw + (s^2_{reg}/2)] \qquad (3)$$

RESULTS

Equation 1 fit the data for each year-class (647≤n≤ 7,708) well as shown by high coefficients of determination, r^2_{adj}, ranging from 0.726 to 0.991 for the first and last year-classes, respectively (Table 1). The same was true (r^2_{adj} = 0.798, n = 65,210) for combined year-classes, but r^2_{adj} was lower for combined year-classes than for individual year-classes due to variation among year-classes. The mean square deviation from regression, s^2_{reg}, ranged from 0.2032

to 0.0075 for the 1978 and 1992 year-classes, respectively (Table 1), showing a significant (P = 0.0001) logarithmic decrease over the year-classes (Figure 3).

There was significant (P < 0.001) heterogeneity in the slope, d, of equation 1 among year-classes, with slowest growth (d = 3.798) in the 1983 year-class and fastest growth (d = 6.929) in the 1985 year-class (Table 1). However, there was no significant trend in d (P = 0.307) over year-classes. Equation 1 parameter estimates (Table 1) were applied to estimate w_{adj} at 1 and 1.22 yr, for each year-

TABLE 1

Regression statistics for the *ln*-linear model (equation 1) of growth in individual weight (w, kg) of head-started Kemp's ridleys (*Lepidochelys kempii*) between ages $0.17 \leq$ to ≤ 1.22 yr in captivity, for each year-class and combined year-classes.

Year-class	n	Intercept, *lnc*	Slope, d	Mean square deviation from regression, s^2_{reg}	Adjusted coefficient of determination, r^2_{adj}
1978	6074	-4.757	4.763	0.2032	0.726
1979	6442	-4.700	4.944	0.1046	0.867
1980	4759	-4.306	4.684	0.0760	0.859
1981	7708	-5.335	5.160	0.0569	0.938
1982	5228	-4.848	4.953	0.1069	0.861
1983	647	-4.415	3.798	0.0786	0.786
1984	5714	-4.667	4.396	0.0994	0.832
1985	6307	-6.040	6.929	0.0694	0.937
1986	4539	-4.302	4.896	0.0542	0.892
1987	4290	-5.705	6.508	0.0476	0.964
1988	2609	-5.225	5.318	0.0108	0.985
1989	3772	-5.183	4.733	0.0179	0.976
1990	2624	-5.538	5.468	0.0121	0.986
1991	2373	-4.679	4.199	0.0076	0.980
1992	2124	-6.066	6.261	0.0075	0.991
Combined	65,210	-5.024	5.167	0.1839	0.798

242
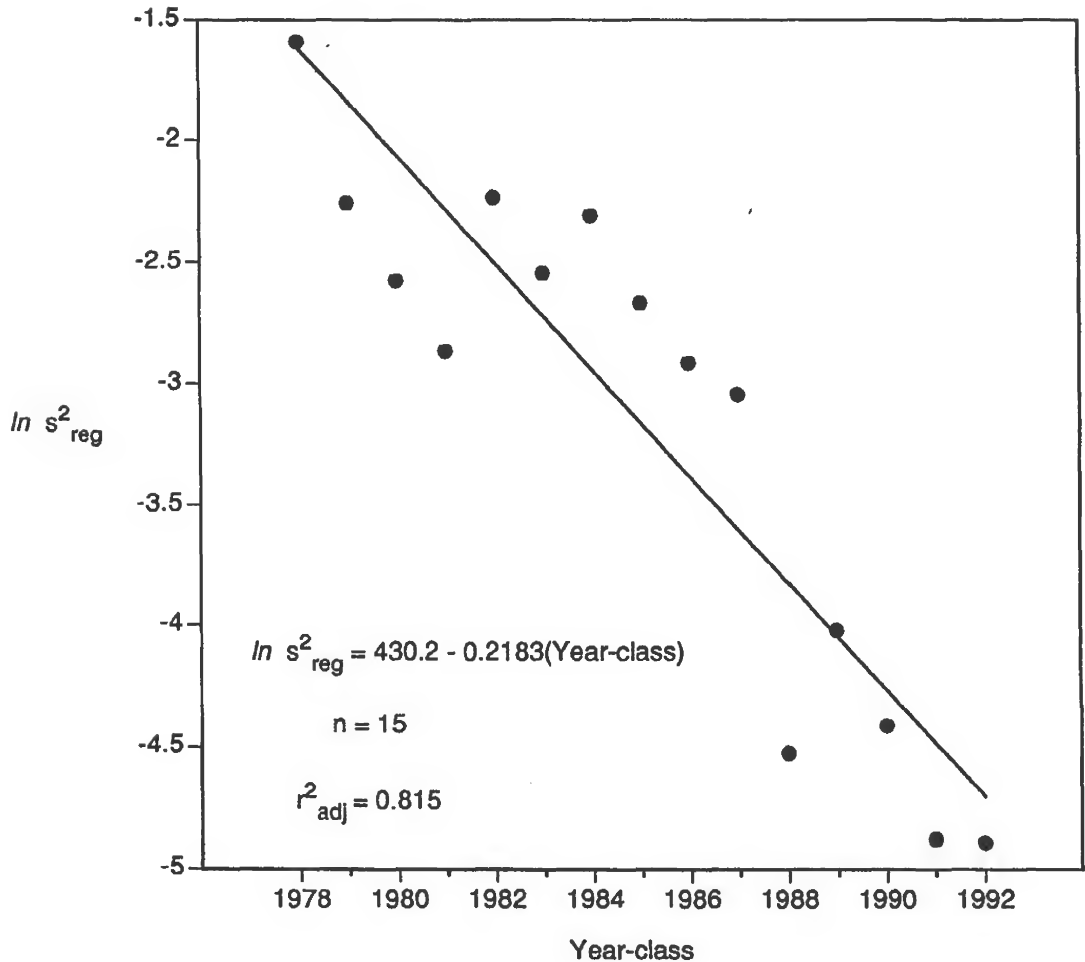
Figure 3. Relationship between lns^2_{reg} for the ln-linear growth model (equation 1) and year-class (1978-1992) in captive-reared Kemp's ridleys (*Lepidochelys kempii*) 0.17 to 1.22 yr of age (t) (see Table 1).

class and combined year-classes (Table 2).

The ln-linear w-scl model (equation 2) applied to the subset of data in which both w and scl were measured (n = 53,317) fit the data well ($r^2_{adj} = 0.994$) for combined year-classes. The intercept (lna) and slope (b) were -8.438 and 2.920, respectively. We substituted w_{adj} estimated from equation 1 for w in equation 2, and solved for scl to obtain scl at 1 and 1.22 yr (Table 2).

DISCUSSION

Exponential growth curves can be generated for each year-class and year-classes combined by detransformation of lnw estimated from linear regression results in Table 1, with an adjustment for bias (equation 3) based on s^2_{reg} obtained in fitting equation 1. An exponential w-scl curve can be derived by detransformation of lnw estimated from equation 2, which also requires an adjustment for bias (equation 3) based on $s^2_{reg} = 0.01198$, obtained in fitting equation 2.

Previous investigators analyzed early growth in captive Kemp's ridleys (Caldwell 1962; Klima and McVey 1982; Caillouet and Koi 1985; Caillouet et al. 1986, 1989; Fontaine et al. 1985, 1989; Landry 1989; Wood and Wood 1989) but these studies were based on fewer observations than ours (65,210 observations from 15 year-classes). Our analyses encompassed and added to the data used by Klima and McVey (1982), Caillouet and Koi (1985), Caillouet et

TABLE 2

Estimates of individual weight adjusted for bias (w_{adj}, kg) and straight carapace length (scl, cm) for head-started Kemp's ridleys (*Lepidochelys kempii*) at age 1 and 1.22 yr, for each year-class and combined year-classes.

Year-class	1 yr		1.22 yr	
	w_{adj}, kg	scl, cm	w_{adj}, kg	scl, cm
1978	1.11	18.6	1.83	22.1
1979	1.34	19.9	2.25	23.7
1980	1.52	20.7	2.47	24.5
1981	0.86	17.1	1.48	20.5
1982	1.17	19.0	1.97	22.6
1983	0.56	14.7	0.83	16.9
1984	0.80	16.6	1.27	19.5
1985	2.52	24.6	5.20	31.6
1986	1.86	22.2	3.10	26.5
1987	2.29	23.8	4.51	30.1
1988	1.10	18.6	1.92	22.5
1989	0.64	15.4	1.06	18.3
1990	0.94	17.6	1.66	21.4
1991	0.62	15.3	0.96	17.7
1992	1.22	19.2	2.35	24.0
Combined	1.26	19.5	2.17	23.4

al. (1986, 1989) and Fontaine et al. (1985, 1989).

The trend of logarithmic decline in the residual variance (s^2_{reg}) of the *ln*-linear growth model (equation 1) was probably due to a shift toward sex ratios dominated by one sex (females), improvements in rearing facilities, year-around control of seawater temperature which reduced disease incidence, improved diet, and reduced feeding levels (Fontaine et al. 1985, 1989; Caillouet et al. 1986, 1989; Leong et al. 1989; Caillouet 1995a). Year-classes 1978-1985 in which both sexes were well represented exhibited greater variation in individual w than those in which most individuals were females, suggesting a possible difference in growth characteristics between the sexes.

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Observations of Sea Turtles and Other Marine Life at the Explosive Removal of Offshore Oil and Gas Structures in the Gulf of Mexico

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OBSERVATIONS OF SEA TURTLES AND OTHER MARINE LIFE AT THE EXPLOSIVE REMOVAL OF OFFSHORE OIL AND GAS STRUCTURES IN THE GULF OF MEXICO

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ABSTRACT Observers monitored the explosive removal of oil and gas structures in the Gulf of Mexico to protect sea turtles and marine mammals from adverse impacts. More than 7,000 monitoring hours at 131 structure removals were conducted during 1993. Sixteen individual sea turtles were observed including 6 loggerheads, 1 Kemp's ridley, 1 green, and 8 unidentified sea turtles. Aerial surveys were approximately ten times more effective in observing sea turtles than day or night surface surveys.

INTRODUCTION

During the summer of 1993 oil and gas production platforms in the Gulf of Mexico totaled nearly 4,000. This number did not include hundreds of smaller, non-producing structures such as well jackets and caissons. Nearly all of these are located in waters off the Louisiana and Texas coasts. Owners are required by federal regulations to remove these structures within one year after lease termination.[1] The most economical removal method utilizes underwater explosives which can have a negative impact on local marine life. During the past four years, explosive structure removals averaged more than 120 annually.

Sea turtles are known to frequent reefs and other areas with submerged structures (Stoneburner 1982; Carr 1954; Booth and Peters 1972; Witzell 1982). Consequently, it is not surprising to find sea turtles at oil and gas structures (Gitschlag and Renaud 1989; Gitschlag and Herczeg 1994; Gitschlag and Hale[2]) which are themselves artificial reefs. Although all five species of sea turtles inhabiting the western Gulf of Mexico are listed as either threatened or endangered, attention to the effects of platform salvage did not occur until 1986. In the spring of that year, 51 sea turtles and 41 bottlenose dolphin (*Tursiops truncatus*) washed up dead on north Texas beaches coincidental with the explosive removal of structures just a few miles offshore (Klima et al 1988). This resulted in a formal consultation authorized under the Endangered Species Act between the National Marine Fisheries Service (NMFS) and Minerals Management Service (MMS), the agencies with jurisdiction

in federal waters. One consequence of the consultation was a procedure requiring oil and gas companies to obtain a permit from MMS prior to using explosives in federal waters. An Incidental Take Statement accompanying the formal consultation prepared by NMFS was included in the permit and described requirements to protect sea turtles (Table 1). Among these requirements was the use of personnel trained to monitor for sea turtles. Similar procedures were established for structure removals in state waters where permits were obtained from the U.S. Army Corps of Engineers (COE).

Mandatory use of trained observers began in 1987. This article summarizes the 1993 findings of the NMFS monitoring program at explosive structure removals in the Gulf of Mexico plus two additional platforms which were originally scheduled for explosives but were actually removed using mechanical techniques.

MATERIALS AND METHODS

Surveys were conducted from helicopters (aerial surveys) as well as from vessels and oil and gas platforms (surface surveys). The area within a 1600 m radius of the removal site was monitored during 30 min pre- and post-detonation aerial surveys at altitudes of 150-200 m, speeds of 100-150 kph, and only during daylight hours. Surface surveys usually began at least 48 hours prior to detonation of explosives and were typically conducted from a vessel positioned immediately adjacent to the structure being salvaged. Surface surveys were occasionally performed at

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TABLE 1

Summary of "Generic" Incidental Take Statement

1. Qualified observers monitor for sea turtles beginning 48 hours prior to detonations.
2. Thirty minute aerial surveys within one hour prior to and after detonation.
3. If sea turtles are observed within 1000 yards of the structure, and detonations and repeat aerial survey.
4. No detonations will occur at night.
5. During salvage-related diving, divers must report turtle and dolphin sightings. If turtles are thought to be resident, pre- and post-detonation diver surveys must be conducted.
6. Explosive charges must be staggered to minimize cumulative effects of the explosions.
7. Avoid use of "scare" charges to frighten away turtles which may actually be attracted to feed on dead marine life and subsequently exposed to explosions.
8. Removal company must file a report summarizing the results.

neighboring structures and, when aerial surveys were waived due to adverse weather conditions, aboard vessels cruising a search pattern within 1,000 m of the structure. Binoculars were used to increase visual acuity when necessary. Estimates of the number of dead, floating fish were made after each detonation and a sample was collected whenever possible. Commercial divers conducted underwater surveys at some structures.

Terminology and data analysis

Certain terminology used in this report requires definition. A sea turtle "sighting" was recorded whenever a sea turtle was observed. If one sea turtle was seen on two separate occasions or if two sea turtles were seen simultaneously, two sightings were recorded. Each sea turtle was counted as a unique "individual" unless there was evidence, for example, barnacle pattern or carapace size, indicating that the same individual appeared repeatedly. Since the occurrence of repetitive sightings could not always be determined, the number of individual sea turtles described in this report represents an upper limit of the actual number observed.

The distinction was made between sightings of sea turtles by trained NMFS personnel and non-NMFS personnel. Unless otherwise noted, results refer to NMFS data. Sea turtles sighted by trained NMFS employees were

recorded as NMFS sightings. Observation "rates" were determined by dividing the number of individual sea turtles by the number of monitoring hours. However, observation rates calculated by time of day used frequencies of sea turtle sightings, not of individual sea turtles, to determine surface activity patterns. All rates refer to NMFS data because monitoring effort was not recorded for non-NMFS personnel.

Visual surveys were cataloged as day, night, and aerial surveys. Day and night surveys were conducted from vessels and platforms and collectively were referred to as surface surveys. Aerial surveys were performed from helicopters. Effort for surface surveys was based on man-hours of monitoring while effort for aerial surveys was based on flight hours regardless of the number of people in the helicopter.

Structures were classified as platforms, caissons, submerged casing stubs, and flare piles. Platforms were defined as multi-pile structures while caissons had only a single pile penetrating the sea floor. Casing stubs were submerged, single pile, well conductors or caissons rising from the sea floor but not reaching the water's surface. Flare piles were defined as single pile structures which supported a flare vent and were located at least 200 m from the nearest platform.

The chi-square test was used to determine differences between test parameters. Categories within test parameters were often pooled to provide acceptable sample sizes since sea turtle sightings occurred infrequently. To facilitate analysis, the study area was divided into five regions: western Louisiana, central Louisiana, eastern Louisiana, north Texas and south Texas (Figure 1).

RESULTS

Overview

One hundred thirty-one offshore structure removals were monitored including 92 platforms, 35 caissons, 2 casing stubs, and 2 flare piles (Table 2). Most removals occurred in relatively shallow water. Twenty-seven percent were in water depths of 15 m or less, 42% in 15-30 m, 26% in 30-60 m, and 5% in greater depths. Sixty percent of platform removals, 91% of caissons, both flare piles, and one of three casing stub removals occurred in water depths less than or equal to 30 m. The deepest removal was a platform in 104 m of water.

Structure removals were monitored across the northwestern Gulf of Mexico from the Louisiana delta to South Padre Island, Texas. Approximately 85% of monitored removals occurred in central and western Louisiana waters between Grand Isle in the east and the

Figure 1. Partitioning of study area into five regional geographic areas (ELA=eastern Louisiana, CLA=central Louisiana, WLA=western Louisiana, NTX=north Texas, STX=south Texas).

Sabine River in the west, while 10% were in eastern Louisiana and 5% in south Texas. No explosive structure removals were reported in north Texas waters.

Energy and salvage companies usually scheduled removals during summer and fall to minimize costs caused by weather delays. Eighty-seven percent of explosive structure removals occurred from June through December.

Monitoring effort

Monitoring effort included 4,009, 2,799, and 220 hours for day, night, and aerial surveys, respectively, for a total of 7,028 hours. Values were highest in central and western Louisiana and in the 15-30 m depth zone (Figure 2a & b).

TABLE 2

Frequency of monitored removals by structure type and water depth.

Water depth (m)	Platform	Caisson	Casing stub	Flare pile	Total	%
≤15	15	20	0	0	35	27
15-30	40	12	1	2	55	42
30-60	30	3	1	0	34	26
60-90	5	0	0	0	5	4
90-120	2	0	0	0	2	1
Total	92	35	2	2	131	
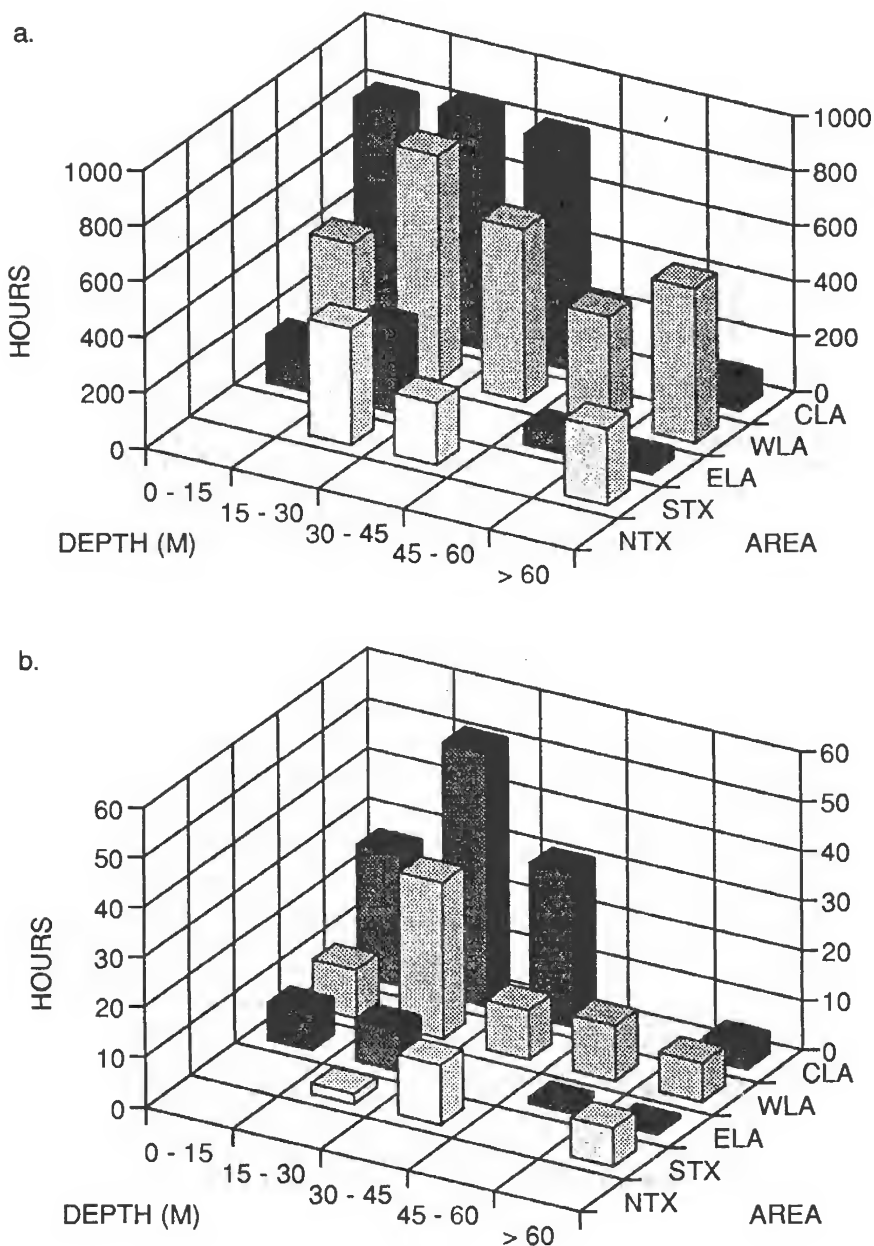
Figure 2. a. Surface monitoring effort by depth and geographic area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana), and b. Aerial monitoring effort by depth and geographic area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana).

Species

Thirty-six sightings of 16 individual sea turtles were made by NMFS personnel. Included were 6 loggerhead (*Caretta caretta*), 1 Kemp's ridley (*Lepidochelys kempii*), 1 green (*Chelonia mydas*), and 8 unidentified sea turtles (Table 3). Additional sightings by non-NMFS personnel increased these values to 47 sightings of 22 individual sea turtles.

TABLE 3

Frequency of sea turtle sightings and individuals. Observations from both NMFS and non-NMFS personnel are included in the "Total" columns.

Species	Sightings		Individuals	
	NMFS	Total	NMFS	Total
Loggerhead	26	30	6	6
Green	1	1	1	1
Kemp's	1	1	1	1
Unknown	8	15	8	14
Total	36	47	16	22

Survey method

Encounters with sea turtles varied by survey method. Sea turtle observation rates for day, night, and aerial surveys were dissimilar (0.0032, 0.0004, 0.0182 individuals per hour, respectively, Table 4). Twenty-eight sightings of 13 individual sea turtles were recorded during day surveys, 2 sightings of 1 individual during night surveys, and 6 sightings of 4 individuals during aerial surveys. When the frequency of sea turtles was adjusted for variations in monitoring effort and analyzed statistically, results showed significant differences between all categories (P<0.0005, Table 5). Comparison of sea turtle observation rates for aerial and surface surveys (day and night combined) showed the aerial survey rate was ten times higher. No sea turtles were observed during diver surveys conducted at 22 structure removal sites despite reported observations of turtles at 19 of these locations.

Structure type

More sea turtles were seen at platforms than at any other structure type. Thirty-one sightings of 15 individual sea turtles occurred at platform removals and 5 sightings of 1 individual at caisson removals (Table 6). An additional 9 sightings at platform removals and 2 sightings at caisson removals were reported by non-NMFS personnel. Although observation rates for surface surveys were approximately 2.5 times higher at platforms than at caissons (0.0022 and 0.0009), rates for aerial surveys were similar (0.0187 and 0.0180). The number of individual sea turtles reported by NMFS personnel per structure removal was 0.16 at platforms and 0.03 at caissons. NMFS observers recorded sea turtle sightings at 8% of the structures monitored while non-NMFS personnel reported sightings at an additional 3% of structures monitored. The occurrence of multiple structure removals at a single location (e.g. separate platforms connected by walkways) served to lower the apparent frequency with which turtles were encountered during surveys. To avoid this artifact, the percentage of monitored lease blocks (measuring approximately 16 sq km each as they appear on MMS lease charts) where turtles were observed was also calculated. NMFS personnel reported turtles at 10% of monitored blocks and this value increased to 16% when non-NMFS sightings were included. Two or more individual sea turtles were observed at three platforms, one each in south Texas, central Louisiana, and eastern Louisiana in water depths ranging from 25-38 m.

Water depth

Thirty of 36 total NMFS sightings occurred in water depths ranging from 15-60 m. This represented 14 of 16 (88%) individuals (Table 7). Sea turtle observation rates for surface surveys were highest for 15-30 m depths (0.0030) while rates for aerial surveys were highest for 0-15 m depths (0.0231, Figure 3 a & b). For depths greater than 60 m the sea turtle observation rate for surface surveys was 0.0012 compared with an aerial rate of zero.

Monthly observations

Sea turtles were reported from surface surveys only during the months of May, August, September, October, and December. Monthly observation rates ranged from 0.0008-0.0054 with the lowest value in September and the highest in October (Table 8). The absence of sea turtle sightings during the remaining months did not always correspond with low monitoring effort and few structure removals.

Aerial surveys sighted turtles during June, August, September and October when observation rates were 0.2762, 0.0287, 0.0153, and 0.0627, respectively.

TABLE 4

Frequency of sea turtle sightings and individuals, monitoring hours, and sea turtle observation rate by structure type. Observations from both NMFS and non-NMFS personnel are included in the "Total" column.

	Platform	Caisson	Casing stub	Flare pile	Total
Sightings				′	
NMFS	31	5	0	0	36
Total	40	7	0	0	47
Individuals					
NMFS	15	1	0	0	16
Total	20	2	0	0	22
Monitoring hours					
Day	3,319	617	47	26	4,009
Night	2,255	527	12	5	2,799
Aerial	160	55	3	2	220
Observation rate					
(individuals/hr)x 10^3					
Day	3.6	1.6	0	0	3.2
Night	0.4	0	0	0	0.4
Day & Night	2.2	0.9	0	0	1.9
Aerial	18.7	18.0	0	0	18.2

TABLE 5

Summary of chi-square analysis. The frequency of individual sea turtles was used in all cases except for time of day where sea turtle sightings were used. Expected values were adjusted for variations in monitoring effort in each category.

Parameters tested	Data Analyzed	N	P	Significant
Day, night, & aerial surveys	All structures	18	<0.0005	*
	Platforms	16	<0.0005	*
Day & night surveys	All Structures	14	<0.0005	*
Depth (0-30, 30-90m)	Day & night surveys	13	<0.7	
Time of day (6 x 4 hr periods)	Day & night surveys	30	<0.005	*

TABLE 6

Frequency of turtle sightings, individuals and structure removals by structure type. Observations from both NMFS and non-NMFS personnel are combined in the "Total" columns.

Structure type	Number of structures removed	Sightings		Individuals		Rate x 10^{-3}		
		NMFS	Total	NMFS	Total	Day	Night	Aerial
Platform	91	31	40	15	20	3.6	0.4	19.0
Caisson	36	5	7	1	2	1.6	0	17.4
Casing stub	2	0	0	0	0	0	0	0
Flare pile	2	0	0	0	0	0	0	0
Total	131	36	47	16	22			

TABLE 7

Frequency of NMFS sea turtle sightings and individuals by depth and structure type. A dash indicates no monitoring was conducted.

Depth(m)	Platform		Caisson		Casing Stub		Flare pile		Total	
	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals
0-15	0	0	5	1	-	-	-	-	5	1
15-30	25	9	0	0	0	0	0	0	25	9
30-60	5	5	0	0	0	0	-	-	5	5
60-90	1	1	-	-	-	-	-	-	1	1
90-122	0	0	-	-	-	-	-	-	0	0
Total	31	15	5	1	0	0	0	0	36	16

a.

b.
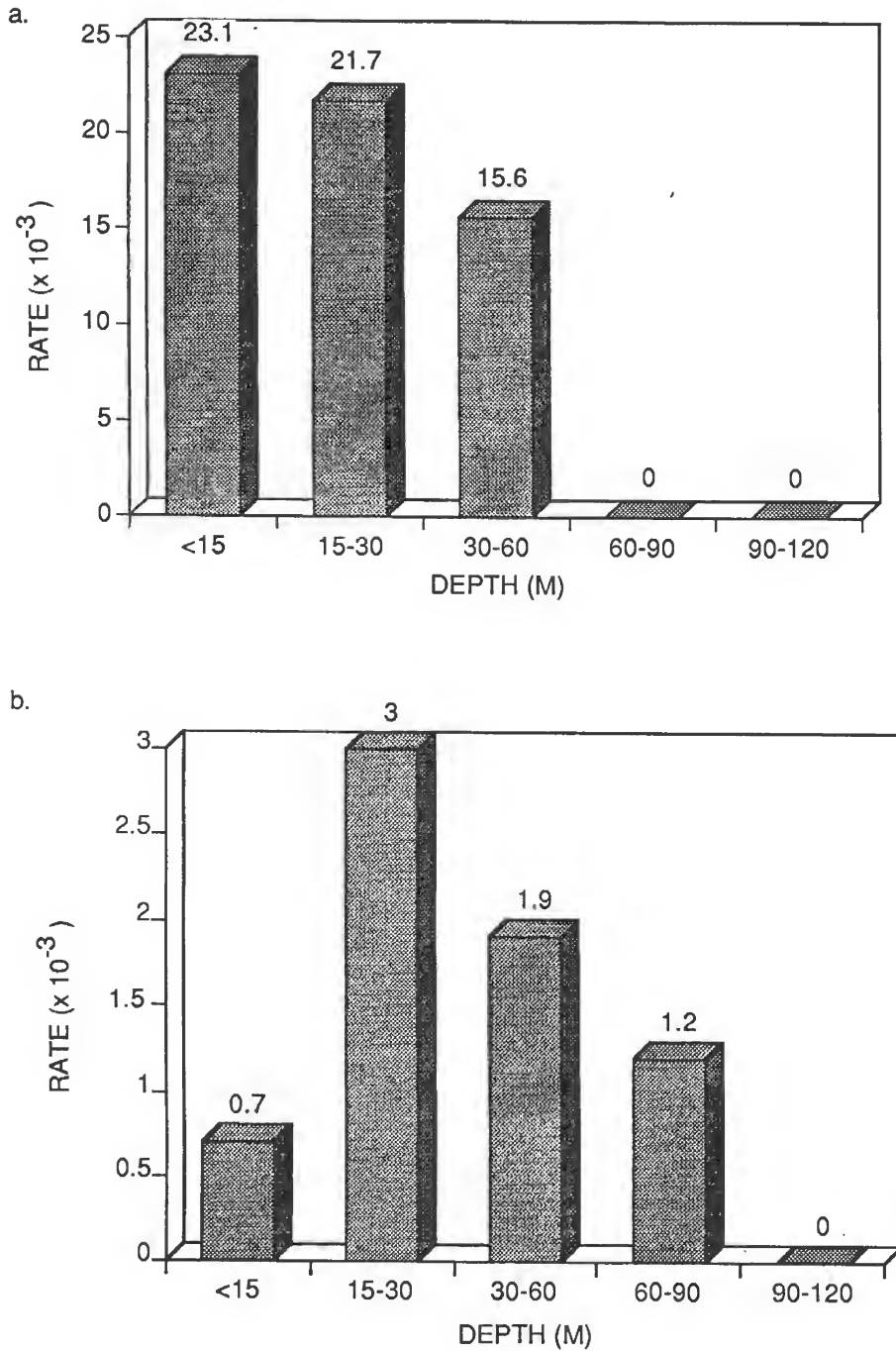

Figure 3. a. Aerial observation rates (individual sea turtles per hour x 10^{-3}) by depth zone, and b. Surface observation rates (individual sea turtles per hour x 10^{-3}) by depth zone.

TABLE 8

Surface and aerial monitoring effort, number of individual sea turtles observed, and observation rate (individuals per hour x 10⁻³) by month.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Surface monitoring hours	405	161	148	161	522	291	999	1,135	1,213	744	635	394
# of individual sea turtles	0	0	0	0	2	0	0	4	1	4	0	2
Rate x 10⁻³	0.0	0.0	0.0	0.0	3.8	0.0	0.0	3.5	0.8	5.4	0.0	5.1
Aerial monitoring hours	11	10	7	5	10	4	31	35	65	16	19	7
# of individual sea turtles	0	0	0	0	0	1	0	1	1	1	0	0
Rate x 10⁻³	0.0	0.0	0.0	0.0	0.0	276.2	0.0	28.7	15.3	62.7	0.0	0.0

Monitoring effort for months with and without sea turtle sightings was generally comparable (Table 8).

Geographic area

No monitoring was conducted in north Texas. Sea turtle observation rates for surface surveys ranged from 0.0004 in western Louisiana to 0.0069 in eastern Louisiana (Table 9). Sea turtles were reported during aerial surveys only in Louisiana waters. Observation rates for aerial surveys were 0.1158, 0.0144, and 0.0089 for eastern, western, and central Louisiana, respectively.

Proximity to structures

Estimates of the proximity of sea turtles to the structure removal site are summarized by survey method (Table 10). Aerial surveys generally provided sightings at greater distances than surface surveys. Fifty-seven percent of sea turtles observed during surface surveys were within approximately 90 meters of the structure compared with 20% during aerial surveys.

Observations by time of day

Surface observation rates for sea turtle sightings were calculated for sequential four-hour time periods of the 24 hour day beginning at midnight. Lower rates generally occurred at night and higher rates during the day (Figure 4a).

TABLE 9

Observation rate (individual sea turtles per hour x 10⁻³) by geographic area (ELA = eastern Louisiana, CLA= central Louisiana, WLA = western Louisiana, NTX = north Texas, STX = south Texas). No monitoring was conducted in north Texas.

	ELA	CLA	WLA	NTX	STX
Aerial observation rate	115.8	8.9	14.4	--	0.0
Surface observation rate	6.9	1.6	0.4	--	4.4

TABLE 10

Frequency of individual sea turtles observed by NMFS personnel by distance from removal structure and survey method. Totals are not additive because some individuals were observed in multiple distance categories and survey methods.

Survey Method	Distance (m)														
	<90		90-450		450-900		900-1350		1350-1800		>1800		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Surface	8	57	3	21	0	0	0	0	0	0	3	21	14	100
Aerial	1	20	2	40	1	20	0	0	1	20	0	0	5	100

The time periods 1600-2000 hr and 0800-1200 hr displayed the highest values, 0.0097 and 0.0069, respectively.

Observation rates for aerial surveys were calculated for only two time periods because surveys were flown only during daylight hours and sample size was small. Rates for 0600-1200 hr and 1200-1900 hr were 0.0188 and 0.0354, respectively (Figure 4b).

Explosives

Amount of explosives used was generally comparable to the number of structures removed and the months, depths, and areas in which the removals occurred (Figures 5 and 6a & b). A total of 16,204 kg of explosives was detonated in 1993. Averages by structure type were 165 kg per platform, 37 kg per caisson, 23 kg per casing stub, and 16 kg per flare pile.

Impacts on sea turtles

Injury and mortality of sea turtles due to underwater explosions was not reported in 1993, although there is earlier evidence of injury and mortality (Klima et al. 1988; Gitschlag and Hale[2]). One green sea turtle was captured and removed from the water prior to detonations thereby precluding any impacts due to explosives.

Fish mortality

Fish killed by underwater explosions either sank to the sea floor or floated to the surface. Although data were unavailable for the former source of mortality, the surface fish kill was estimated at 63,500. Of these, approximately 58,300 were killed during the removal of platforms, 5,000 at caissons, 200 at casing stubs, and none at flare pile removals. The estimated number of dead,

floating fish by structure type was 650 per platform, 140 per caisson, and 100 per casing stub. Estimates of the number of fish killed by geographic area and depth generally corresponded with peaks in explosives use (Figures 6a & b and 7a). Exceptions were identified by calculating the ratio of estimated fish kill per kg of explosive. Highest ratios were 6.1 and 5.7 for western and central Louisiana in 30-45 m depths. The dominant species in descending order of abundance included red snapper (*Lutjanus campechanus*), Atlantic spadefish (*Chaetodipterus faber*), sheepshead (*Archosargus probatocephalus*), blue runner (*Caranx fusus*), lane snapper (*Lutjanus synagris*), mangrove snapper (*Lutjanus griseus*), vermilion snapper (*Rhomboplites aurorubens*), and tomtate (*Haemulon aurolineatum*).

Marine mammals

Observational data provided a crude index of marine mammal activity at structure removal locations. Sightings totaled over 1700 and included primarily the Atlantic bottlenose dolphin, *Tursiops truncatus*, although spotted dolphin, *Stenella plagiodon*, were also reported. Marine mammals were observed at 56 of 77 lease blocks monitored or 73%. On average, 17 dolphin sightings were recorded per platform removal, 5 per caisson removal, 31 per casing stub removal, and zero per flare pile removal. The highest number of dolphin sightings occurred in western and central Louisiana at depths of 15-30 and 30-45 m (Figure 7b). These areas also ranked in the top five for monitoring effort. The number of sightings in central Louisiana at 30-45 m depths was exceptionally high, more than double any other value. In contrast, marine mammal sightings in central Louisiana at 0-15 m depths were very low in relation to the level of monitoring effort.
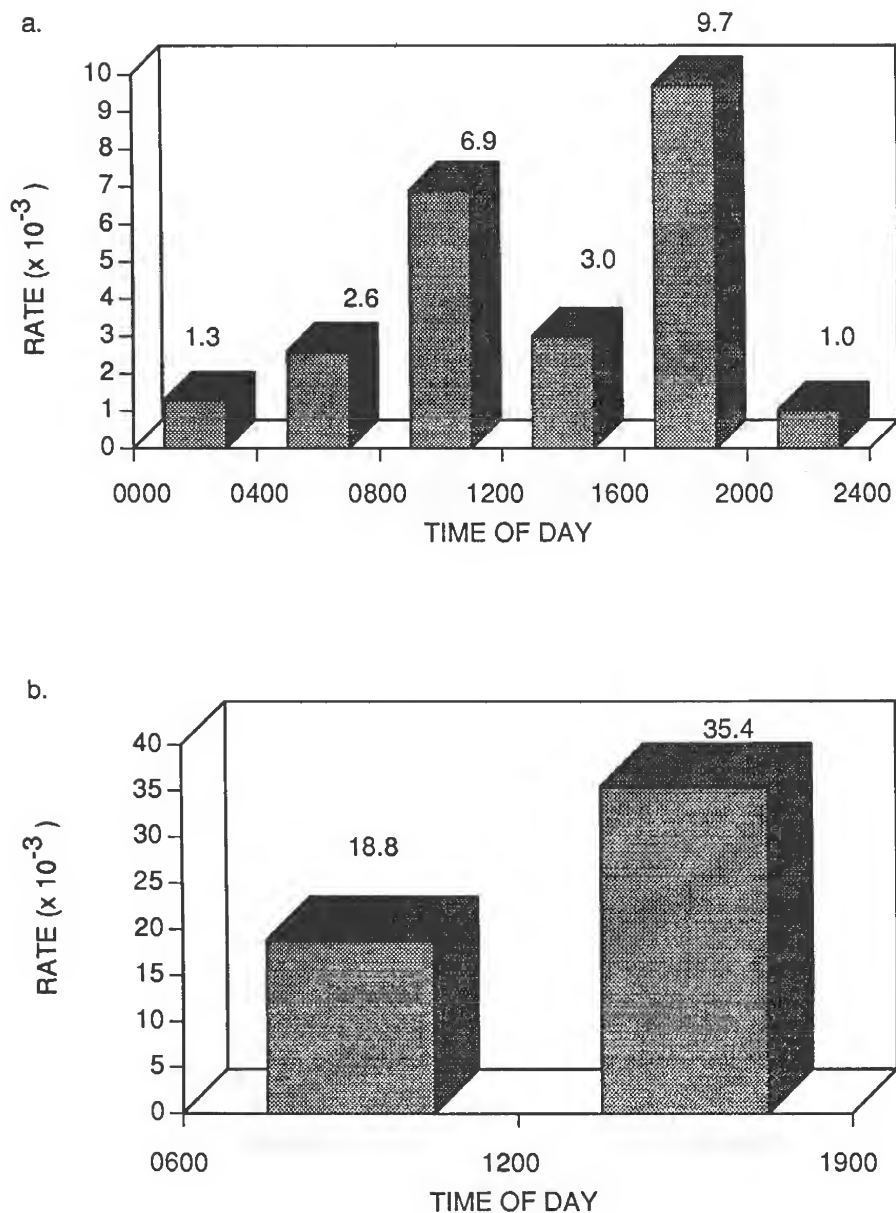
Figure 4. a. Rate (sightings per monitoring hour x 10^{-3}) of sea turtle sightings from surface surveys by time of day, and b. Rate (sightings per monitoring hour x 10^{-3}) of sea turtle sightings from aerial surveys by time of day. Aerial surveys were only conducted during daylight hours.
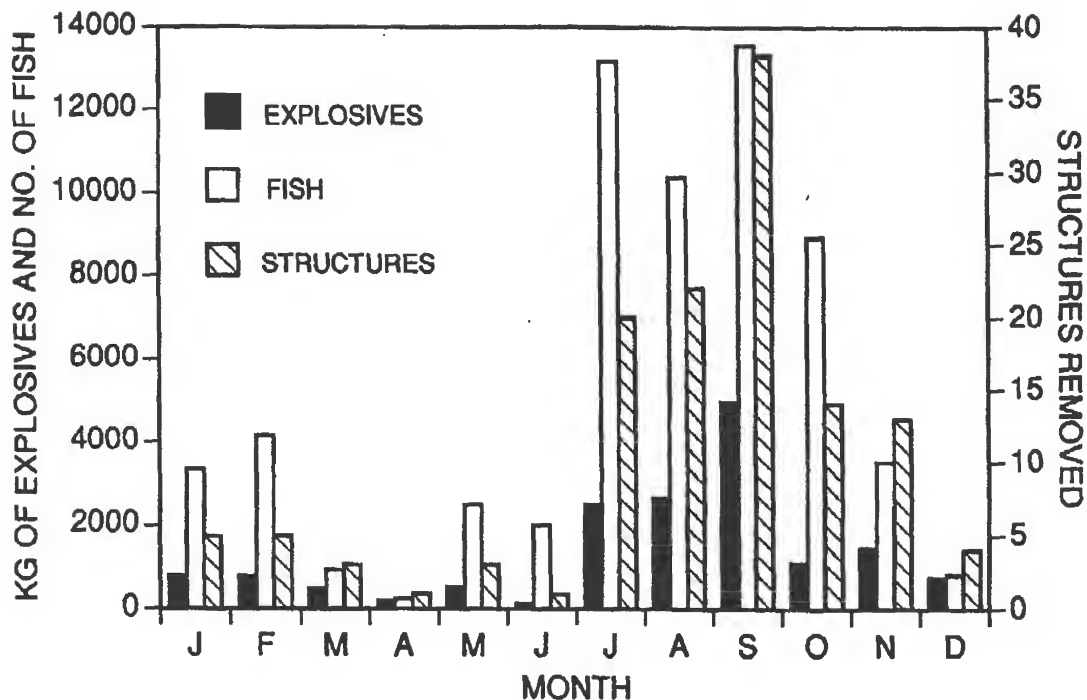
Figure 5. Estimated number of dead, floating fish, kilograms of explosives used, and structures removed by month.

DISCUSSION

Aerial and surface surveys

The aerial observation rate of sea turtles was ten times higher than the surface rate. This value was approximately the same as the six year average (1986-1991), which attests to the superiority of aerial surveys. However, results were less consistent than in earlier years. The failure of aerial surveys to detect sea turtles in south Texas when surface surveys identified 4 individuals may be due to several factors. Dive duration of sea turtles can easily exceed the 30 minute flight time of aerial surveys, and sea turtles may have been undetected because they were submerged during helicopter surveys. Alternatively, the turtles observed during surface surveys may have moved out of the area prior to commencement of aerial surveys.

Months and areas with high sea turtle observation rates often varied between aerial and surface surveys. The causes of these differences were not positively identified but were probably related to small sample size. Sea turtles are listed as threatened and endangered because they are relatively few in numbers. Consequently, encounters with sea turtles are infrequent events.

Explosives

Although the amount of explosives used per caisson and casing stub in 1993 was similar to the six year average (1986-1991 Gitschlag and Hale[2]), the weight of explosives used per platform more than doubled in 1992 (Gitschlag and Herzceg 1994) and continued to increase in 1993. This occurred despite a decrease from 11 to 7 in the average number of pilings (including pilings, skirt pilings, conductors, dolphin pilings, and flare pilings) for each platform removal. On average, more explosives were used to sever each piling than in the past.

Impacts on sea turtles

The dominant species of turtle observed at explosive structure removals is the loggerhead which is classified as a threatened species in contrast to the other turtle species which are endangered. Impacts of explosive removals on sea turtles are not easily assessed primarily because turtle behavior makes observations difficult. Sea turtles in temperate latitudes generally spend less than 10% of their time at the surface (Byles 1989; Kemmerer et al. 1983; Nelson et al. 1987; Renaud and
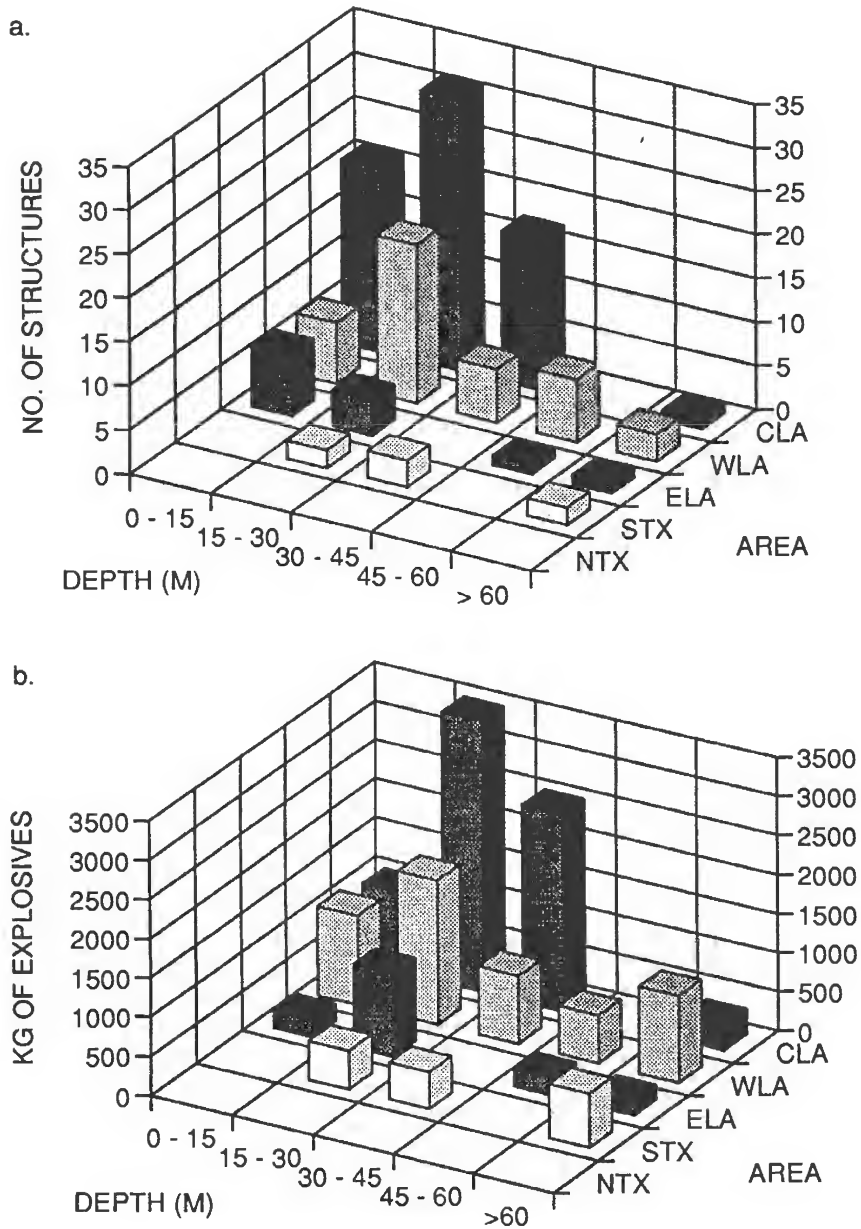
Figure 6. a. Number of explosive structure removals by area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana) and depth (data include four monitored platforms that were removed without explosives), and b. Explosives (kg) use by area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana) and depth.

Figure 7. a. Estimated number of dead, floating fish by area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana) and depth, and b. Dolph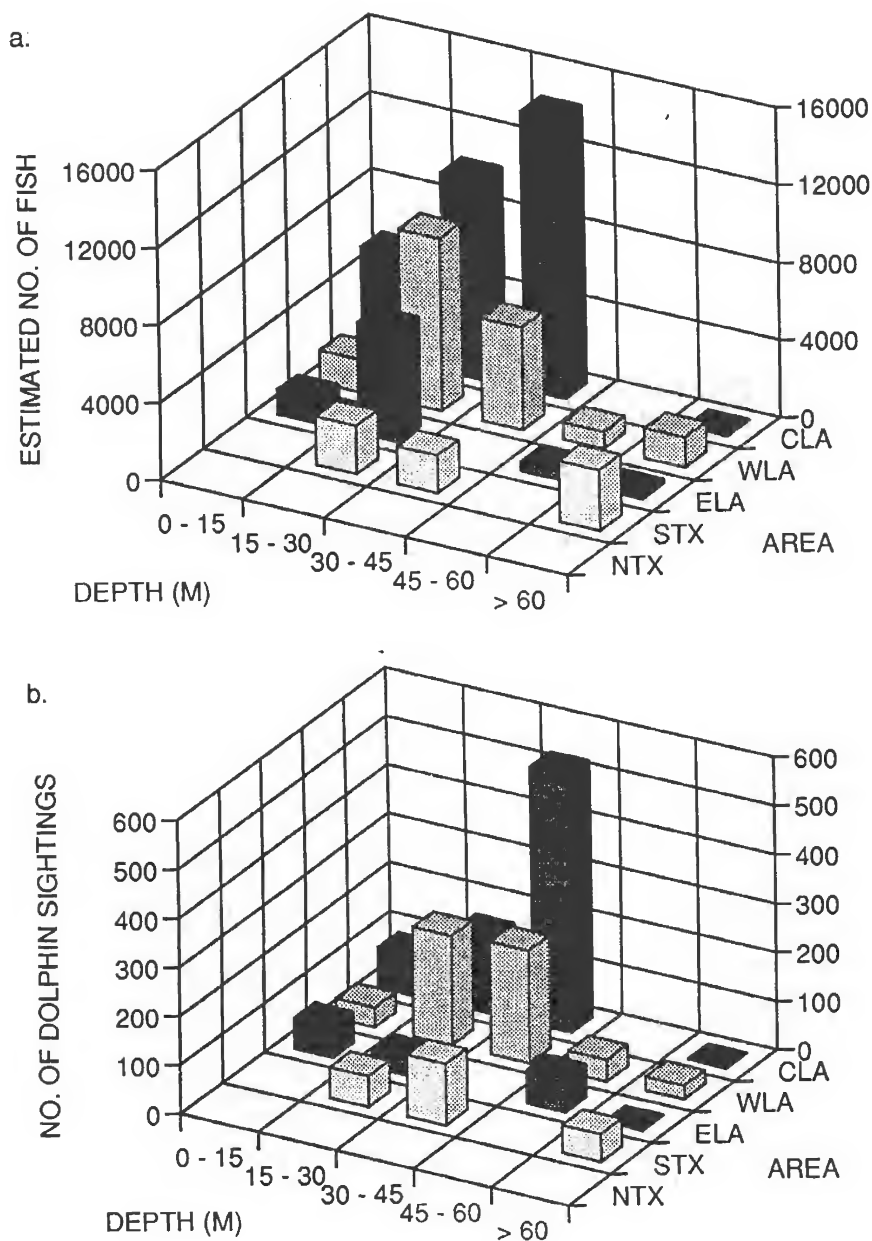in sightings by area (NTX=north Texas, STX=south Texas, ELA=eastern Louisiana, WLA=western Louisiana, CLA=central Louisiana) and depth.

Carpenter 1994; Renaud submitted) and dive durations can exceed one hour (Byles 1989; personal observation by author). Injured sea turtles that are capable of swimming return to the surface while moribund turtles sink to the sea bottom. Although federal regulation (30 CFR 250.4(b), NTL No. 92-02) requires the use of trawls to verify structure removal locations are clear of obstructions and debris present as a result of oil and gas activities, this procedure is ineffective in collecting impacted sea turtles because contractors have up to 60 days after removal to complete the work. In addition, explosives are detonated over periods of days, weeks, and even months during platform removals, and carcasses can be removed from the area by currents or predators. Without a thorough survey of the sea floor after each detonation, only a conditional assessment of impacts can be made.

With an estimated 1,000 structures or more planned for removal between 1990 and 2000 (National Research Council Marine Board 1985), there is considerable potential for sea turtles to be adversely impacted. High levels of mortality could result if explosives are used when sea turtles occur in aggregations such as during breeding and occasionally during feeding. The monitoring program described here should identify such situations and provide advance notice to managers who can require the implementation of special safety precautions. However, compared with incidental capture in fishing gear, degradation of nesting habitat, and poaching (Henwood and Stuntz 1987; Federal Register 1987; Magnuson et al. 1990; Redfoot et al. 1990; Ehrhart et al. 1990; Broadwell 1991; Donnelly 1991; Irvin 1991; LeBuff and Haverfield 1991), explosive structure removals have had a relatively minor impact on sea turtles.

Sea turtles were observed at 13% of the structures monitored. Aerial surveys were ten times more effective than surface surveys in detecting the presence of sea turtles. Dolphins occurred much more frequently than sea turtles at structure removals. No sea turtles or marine mammals were reported injured or killed by explosives during 1993. Estimates of dead, floating fish indicated mortalities were highest for red snapper, Atlantic spadefish, and sheepshead.

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DISTRIBUTION AND ABUNDANCE OF CHAETOGNATHA ON THE YUCATAN SHELF DURING MAY, 1986.

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ABSTRACT An analysis of chaetognath species distribution and abundance from the Yucatan Shelf during May 1986 is presented. Zooplankton samples and associated hydrographic data were collected at 21 stations off the northern and northwestern coasts of the peninsula. Density data were classified and analyzed by calculating the Euclidian distance. In addition, the Importance Value of the species was obtained. Highest abundance (1000 to 5000 orgs./100m^3) occurred in the northern and northwestern zones off the peninsula, while species richness was higher at oceanic stations farther offshore. The most abundant and frequent species were *Sagitta enflata* and *S. bipunctata*. The classification analysis based on the Euclidian distance showed three zones in the study area with different predominant species: (1) The northeast oceanic region of the Peninsula, with *S. minima, S. serratodentata, S. enflata* and *S. bipunctata*; (2) the west and northwest neritic region with *S. enflata* and (3) the near northeast and west coastal region with *S. bipunctata*.

INTRODUCTION

Besides being an important oil zone, the Campeche Bank comprises areas of high biological productivity (Bessonov et al., 1971). Most Cuban and Mexican fishing activity is done in these waters. Among the commercial species, one can find the blue fin tuna, *Thunnus thynnus*, fish of the families Pomadasidae, Sparidae, Lutjanidae and Serranidae, as well as crustaceans such as shrimp and lobster. Enhanced exploitation of these resources requires more complete knowledge of the zooplankton community.

Among the studies focused on chaetognaths carried out in the Caribbean zone, we highlight the works of Furnestin (1965) in the Antilles, Suárez-Caabro (1955) on the coasts of Cuba and Michel and Foyo (1976) and Michel (1984) for the entire Caribbean Sea. On the southeast coast of the United States, Owre (1960) and Pierce and Wass (1962) investigated the chaetognaths of the Florida Current. In the northern Gulf of Mexico, Pierce (1962) investigated the chaetognaths on the Texas coast and McLelland (1984, 1989) studied the distribution of coastal and oceanic chaetognaths and prepared a key to their identification. For the southern Gulf of Mexico, Vega-Rogríguez (1965) focused on the coast off Veracruz, Mexico and Rivero-Beltrán (1975) studied the abundance of chaetognaths of the Campeche Bank, Mexico.

At present, the Advanced Investigation Center-I.P.N. Mérida Campus (CINVESTAV-IPN-Mérida) is performing a series of oceanographic cruises over the Campeche Bank which include the collection of zooplankton samples. Meanwhile, the Ecology Laboratory of the National School of Biological Sciences (ENCB-IPN, Mexico City) has carried out several zooplankton investigations on this community in the same zone since 1979 (Guzmán del Proo et al., 1986; de la Campa et al., 1987). This paper, based on the latter investigations, intends to continue these studies by reporting the Chaetognatha species composition, spatial distribution and density on the Campeche Bank during May 1986.

Study Area

The continental shelf that surrounds the Gulf of Mexico broadens off the coast of Texas, Florida and the Yucatan Peninsula. The Yucatan Shelf, also known as the Campeche Bank, surrounds the Yucatan Peninsula on its north and west sides. It comprises an area with a gentle slope that extends out to depths of 200 m.

The system of currents in the Gulf is dominated by the Yucatan Current (Nowlin 1971, Suárez and Gasca 1989). The movement of this current along the Yucatan Shelf contributes to the upwelling of nutrient-rich water along the northeastern edge of the shelf and the central portion of the Campeche Bank (Gasca and Suárez 1991).

Bessonov et al. (1971) divided the Yucatan Shelf into two regions, the western and eastern zones, according to circulation patterns. They also established two types of circulation. The first occurs when the intensity of the Yucatan Current increases during the rainy season, causing a cyclonic circulation in the eastern zone. The second takes place when the intensity of the Yucatan Current decreases during the dry season. As a consequence, patterns of cyclonic and anticyclonic circulations are developed in the northern and western regions of the shelf from November through March.

MATERIALS AND METHODS

Twenty-one zooplankton samples were collected by the CINVESTAV-IPN.Mérida staff in May 1986 aboard the oceanographic ship *Justo Sierra*. Sampling stations were located on the Yucatan Shelf between 19° 25'24"N and 86° 10'93"W (Figure 1, Table 1). At each station, temperature, salinity and dissolved oxygen values were recorded from the surface level (0-50m), and zooplankton sampling was performed by oblique tows using bongo type nets (333 μm mesh). Settled volume of zooplankton was measured as an estimate of biomass. Afterwards, the chaetognaths were removed from sample aliquots for enumeration and identification.

Chaetognath density was standardized and reported as number of orgs./100m³, and species richness was calculated. The data gathered was then classified and analyzed by the Euclidian distance to detect distribution patterns of the species in the Campeche Bank, according to methods described by Crisci (1983). In addition, the Importance

Value (IV) (Krebs, 1978) was obtained, using only the density and frequency of the species.

RESULTS

Environmental Conditions

Two areas were detected with high surface temperatures (27°C), one off the west side of the Peninsula near the coast, and the second to the far northeast side of the study zone (Figure 2). The lowest records of surface temperature (22°C), were found off the northern part of the Peninsula, over the shelf. In this zone, a westward gradient of 22-25°C was observed. The lowest surface salinity obtained was 36.2‰ off both, the eastern and western sides of the peninsula. The highest value was 37‰ off Campeche. Oxygen in surface waters was highest (5.0 ppm) in the oceanic region to the north and west of the peninsula above the 50 m isobath. For the rest of the study zone, values of 4.7-4.9 ppm were registered.
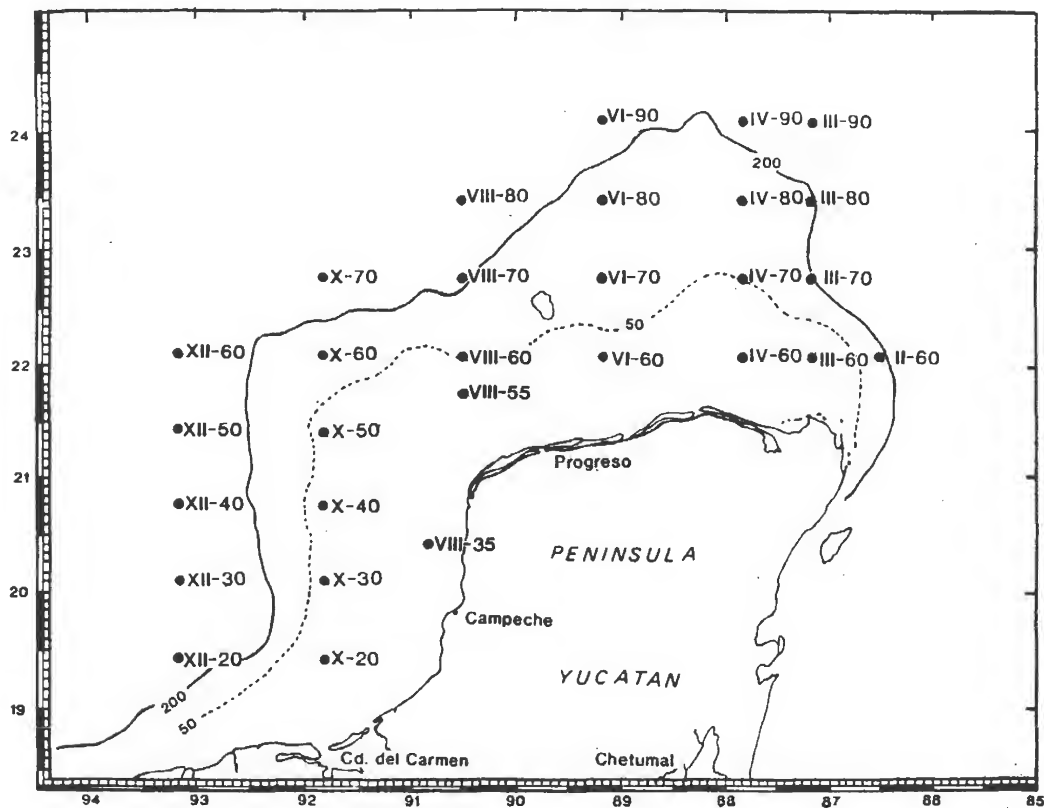
Figure 1. Sampling stations during the Oceanographic Cruice "Yucatan VI" carried out in Yucatan Shelf, Mexico. May 1986.

TABLE 1

Biomass, abundance and species richness of Chaetognatha in Yucatan shelf, Mexico, May 1986.

Station	Position	Sampling depth (m)	Biomass (ml / 100m³)	Abundance (org./100 m³)	Number of species
II- 60	22° 05' 86° 30'	99.2	43.5	660	3
III-60	22° 05' 87° 30'	14.7	62.8	1680	4
III-80	23° 25' 87° 10'	101.1	11.0	159	7
III-90	24° 05' 87° 10'	102.2	12.3	266	7
IV-70	22° 45' 87° 50	30.1	44.7	478	6
IV-80	23° 25' 87° 50'	64.8	11.9	549	7
IV-90	24° 05' 87° 50'	104.3	6.9	414	7
VI-60	22° 04' 89° 10'	35.0	265.3	8000	5
VI-80	23° 24' 89° 09'	92.7	48.2	761	6
VIII-35	20° 25' 90° 50'	4.7	49.4	848	2
VIII-55	21° 15' 90° 28'	9.9	26.2	386	3
VIII-60	22° 05' 90° 30'	25.0	45.6	697	5
VIII-70	22° 45' 90° 29'	110.2	13.4	906	7
VIII-80	23° 25' 90° 30'	106.6	8.3	548	7
X-20	19° 24' 91° 50'	22.0	62.4	3358	5
X-50	21° 25' 91° 50'	29.6	57.8	989	5
X-60	22° 05' 91° 50'	52.9	93.1	1757	4
X-70	24° 45' 91° 49'	108.5	19.0	799	7
XII-30	20° 05' 93° 10'	94.2	23.9	829	7
XII-40	20° 45' 93° 10'	83.5	36.5	652	7
XII-60	22° 05' 93° 10'	97.0	23.2	1091	6
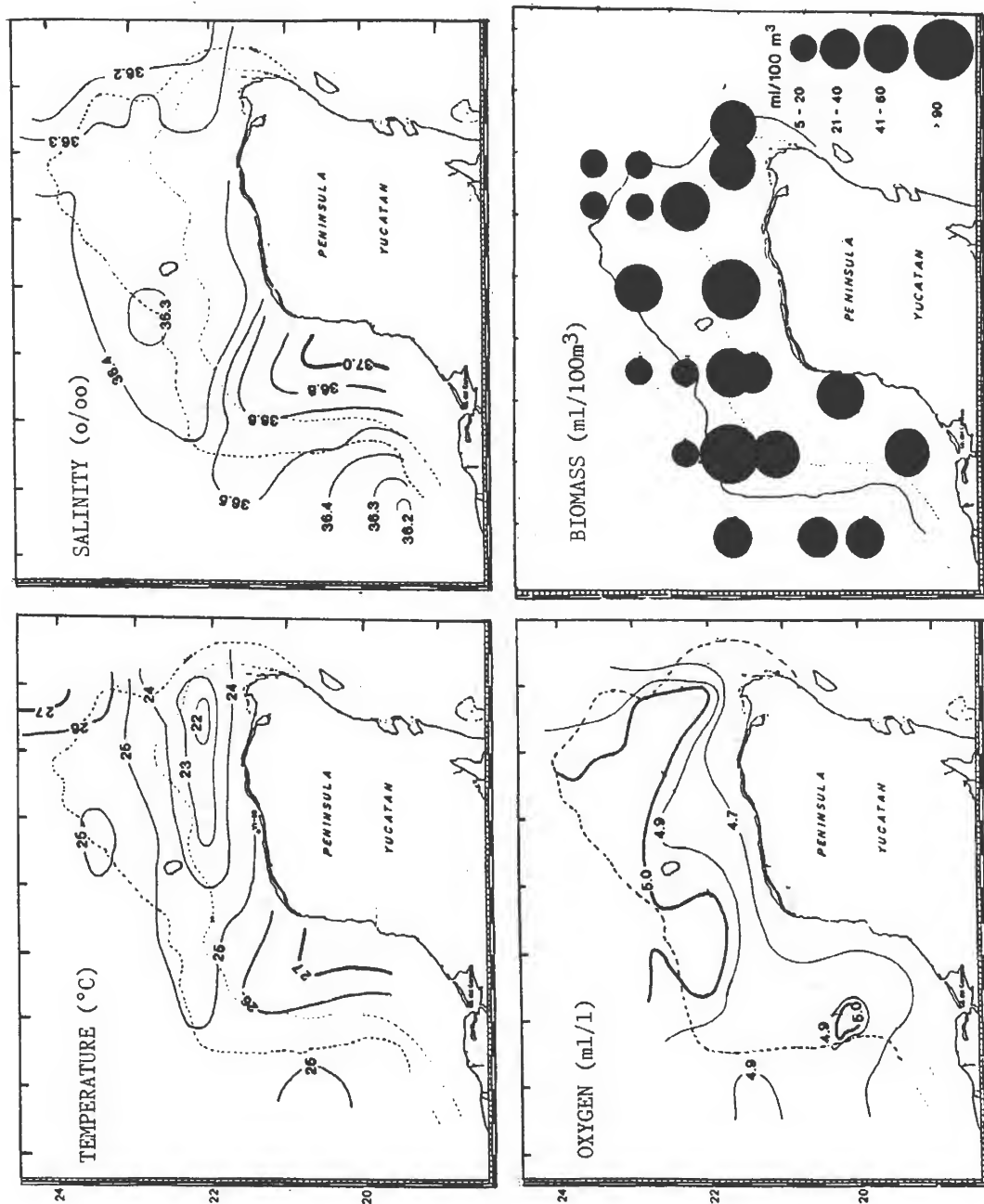
Figure 2. Horizontal distribution of shallow water temperature, salinity, oxygen and total plankton biomass, Yucatan Shelf, Mexico, May 1986.

Biological Characteristics

The lowest biomass (6.9-36.5 ml/100m³) occurred in the northern oceanic zone and over the slope (200 m isobath). Values on the Yucatan Shelf ranging from 26.2 to 265.3 ml/100m³ (Figure 2, Table 1). Highest abundance (>5000 orgs./100m³) was found in one shallow near-coastal station (VI-60), while values from 1001 to 5000 orgs/100 m³ occurred in the northeastern and northwestern zones off the peninsula. Off the northern peninsula, beyond the 50 m isobath, chaetognath density ranged from 158 to 500 orgs./100m³ (Figure 3, Table 2).

Species richness was higher at oceanic stations (Figure 3, Table 1), with nine species belonging to the genera *Krohnitta*, *Pterosagitta* and *Sagitta*. The rank of importance, calculated from the Importance Value, is as follows:

| Species	IV
Sagitta enflata (Grassi, 1881)	145.6
Sagitta bipunctata (Quoy and Gaimard, 1827)	124.2
Sagitta serratodentata (Kronhn, 1853)	89.7
Sagitta minima (Grassi, 1881)	79.7
Pterosagitta draco (Kronhn, 1853)	75.9
Krohnitta subtilis (Grassi, 1881)	68.8
Sagitta hexaptera (d'Orbigny, 1843)	58.4
Krohnitta pacifica (Aida, 1897)	9.6
Sagitta friderici (Ritter-Zahony, 1899)	4.9

Based on these values, three species groups were detected:

First set (IV:> 100). Most abundant and frequent species included *Sagitta enflata* and *S. bipunctata*, which

TABLE 2

Abundance (org./100 m³) of Chaetognaths Species in the Yucatan Shelf, Mexico. May, 1986. (Kp-*Krohnitta pacifica*, Ks-*K. subtilis*, Pd-*Pterosagitta draco*, Sh.-*Sagitta hexaptera*, Se-*S. enflata*, Ss-*S. serratodentata*, Sb-*S. bipunctata*, Sm-*S. minima*, Sf-*S. friderici*).

| Station	Species									
	Kp	Ks	Pd	Sh	Se	Ss	Sb	Sm	Sf	TOTAL
II-60	0.0	0.0	0.0	0.0	25.3	12.6	622.5	0.0	0.0	660
III-60	0.0	0.0	0.0	0.0	370.4	66.1	780.6	463.1	0.0	1680
III-80	0.0	15.5	28.5	2.5	38.9	46.7	18.1	7.7	0.0	158
III-90	0.0	2.7	96.0	2.7	120.7	35.6	5.4	2.7	0.0	266
IV-70	0.0	7.9	95.1	0.0	137.7	79.2	142.6	0.0	15.8	478
IV-80	0.0	21.8	59.6	7.9	97.4	35.7	137.1	89.4	0.0	549
IV-90	0.0	20.7	55.4	37.1	177.3	20.7	37.4	65.1	0.0	414
VI-60	0.0	326.5	244.8	0.0	3102.0	0.0	3755.1	571.4	0.0	8000
VI-80	22.0	0.0	88.2	0.0	264.8	55.1	44.1	286.8	0.0	761
VIII-35	0.0	0.0	0.0	8.2	0.0	0.0	840	0.0	0.0	848
VIII-55	0.0	13.0	0.0	0.0	229.0	0.0	143.9	0.0	0.0	386
VIII-60	8.2	0.0	0.0	0.0	614.1	24.8	41.4	8.2	0.0	697
VIII-70	0.0	20.2	117.8	30.3	273.1	208.8	138.0	117.8	0.0	906
VIII-80	0.0	25.0	69.5	5.5	164.1	91.8	148.8	43.1	0.0	548
X-20	0.0	0.0	62.4	31.2	3123.7	15.6	124.9	0.0	0.0	3358
X-50	0.0	10.5	0.0	0.0	768.2	10.5	178.9	21.0	0.0	989
X-60	0.0	0.0	16.5	165.7	1158.3	16.5	0.0	0.0	0.0	1757
X-70	0.0	25.4	112.0	15.2	468.5	76.3	61.1	40.7	0.0	799
XII-30	0.0	6.3	19.1	6.3	599.4	89.2	76.5	31.8	0.0	829
XII-40	0.0	38.9	29.2	29.2	321.2	38.9	19.4	175.2	0.0	652
XII-60	0.0	38.1	61.9	0.0	567.2	100.1	95.3	228.8	0.0	1091
TOTAL	30.2	573.0	1156.0	342.0	13021.3	1024.2	7411.2	2152.8	15.8	25830
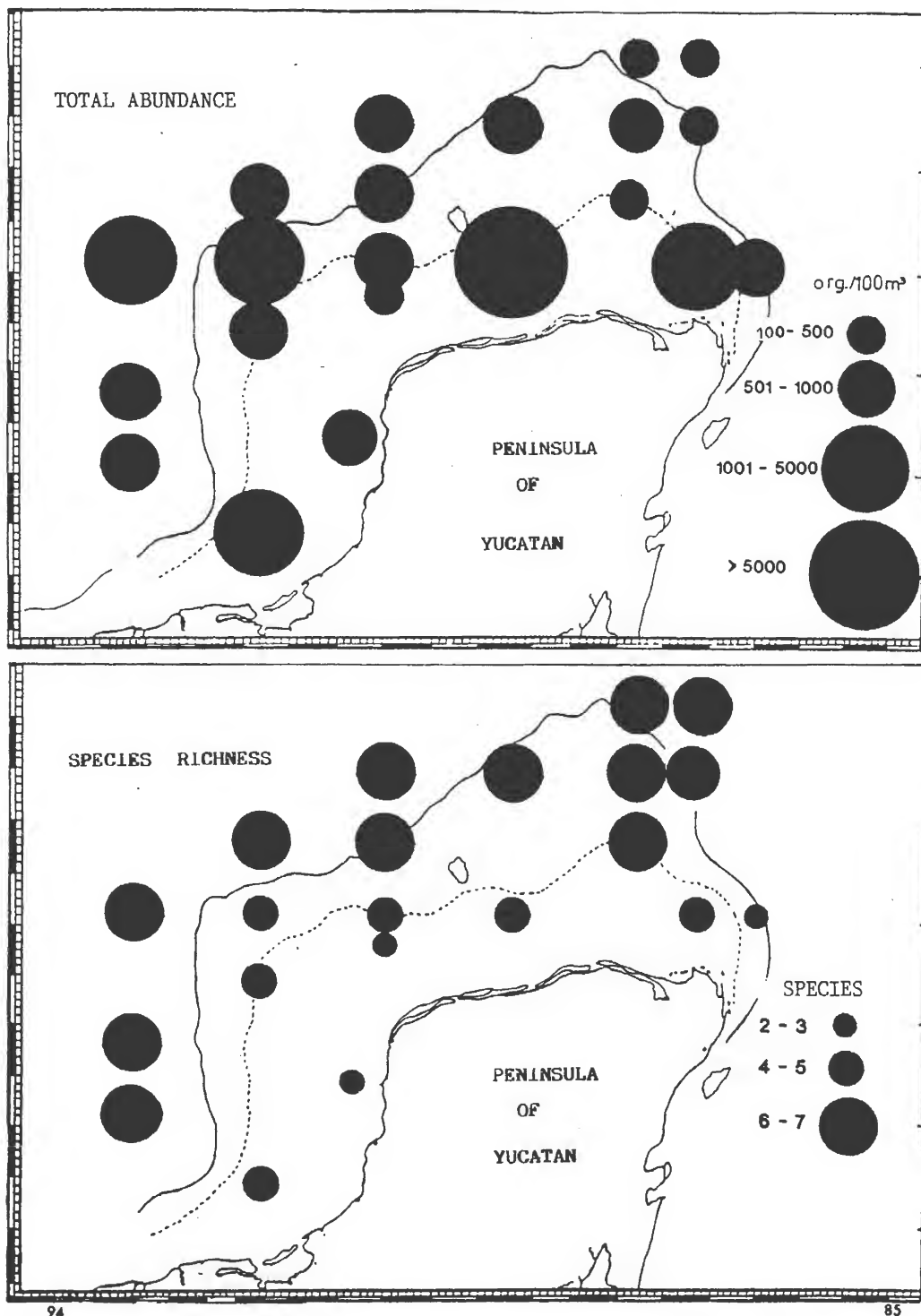
Figure 3. Total abundance and species richness of Chaetognaths. Yucatan Shelf, Mexico, May 1986.

are broadly distributed in the study area. The first was found mostly in the west, while the second was most abundant in the shallow near-coastal zone to the north of the peninsula and off the Campeche coast (Figure 4, Table 2).

Second set (IV: 50-80). Species with regular abundance and frequency included *Sagitta serratodentata, S. minima, Pterosagitta draco, Krohnitta subtilis* and *S. hexaptera*. These were found mainly in the northern part of the study area (Figure 5).

Third set (IV: < 10). Less frequent and abundant species included *Sagitta friderici* and *Krohnitta pacifica*, which were present at only one and two sampling stations, respectively, towards the northern part of the shelf (Table 2).

In the oceanic region, to the northeast and north of the peninsula, there was no evident dominance by a particular species (Figure 6). In this region, *Sagitta bipunctata, S. minima, S. enflata* and *S. serratodentata* comprised between 26 and 50% of the collected individuals.

From the dendrogram constructed using dissimilarity values obtained with the Euclidian distance Index (Figure 7), three groups of samples are distinguished: (1) most of the samples found off the northern part of the peninsula near the slope; (2) those located over or near the slope west of the peninsula and (3) those found over the shelf near shore, to the northeast and west of the peninsula.

DISCUSSION

Previous investigations in the Gulf of Mexico and the Caribbean Sea coincide in placing the Campeche Bank among the zones with the highest productivity in the Gulf, a fact that is reflected in its high planktonic biomass values (Bogdanov et al. 1968; Jromov 1965, De la Cruz 1971). Bogdanov et al. (1968) also mentioned that this is a zone where upwelling takes place often throughout the year and the highest biomass occurs during the rainy season when upwelling increases.

During May 1986, the highest biomass values were recorded over the Campeche Bank (Figure 2) and towards the western oceanic region, while the values were relatively low in the northern and northeastern oceanic regions. The total chaetognath density (Figure 3) presented a similar distribution to that of biomass, with highest values found mostly over the shelf, a fact also reported by Juárez (1975) for fish eggs and larvae.

The species number was high at oceanic stations beyond the 50 m isobath, but specific abundance was low (Figure 3). This relationship is better observed in the northeast region of the zone. Jromov (1965) pointed out that this relationship between abundance and specific richness appears frequently in tropical waters due to the

stability of oceanographic conditions. Meanwhile, the changing conditions of the shallow near-coastal zone only allows the development of some species.

Most of the identified species in this study have been reported by other authors as common in the Caribbean Sea (Suárez-Caabro 1955; Michel and Foyo 1976). *Sagitta enflata* was prominent in those reports and in this study because of its high abundance. If we consider the current entering the Gulf through the Yucatan Channel to be an extension of Caribbean waters, we should expect to find the same epiplanktonic species in both regions. The majority of the recorded species in this study are oceanic, epiplanktonic and cosmopolitan in tropical and subtropical waters. Only *Sagitta friderici* and *S. serratodentata* are reported to be distributed exclusively in the Atlantic Ocean. Because of their epiplanktonic nature, the identified species are associated with surface tropical water masses (Alvariño 1969; Michel and Foyo 1976) and can tolerate broad variations in salinity and temperature brought about by evaporation, precipitation and fluvial discharge.

Sagitta enflata (Grassi 1881) is epiplanktonic, widely distributed and the most abundant in tropical and subtropical regions (Alvariño 1969; McLelland 1989). *Sagitta enflata* was present throughout the study area with high abundance levels (Figure 4). To the west of the peninsula, it represented a high percentage of all identified organisms (Figure 6) and coincided with high values of temperature and salinity (25-27°C and 36.4-37.0‰).

Sagitta bipunctata (Quoy and Gaimard 1827) is epiplanktonic in tropical and subtropical regions and is considered oceanic and scarce in the Caribbean Sea and Gulf of Mexico (Michel and Foyo 1976, Rivero-Beltrán 1975). In the present study, *S. bipuncata* had a conspicuously neritic distribution and was the second in abundance throughout the study area (Figure 4). Its relative abundance was low, except for two stations near the coast at the northeast and west side of the peninsula where its abundance ranged between 76 and 99% (Figure 6). Its presence coincided with the highest and lowest salinity and temperature values, suggesting a wide tolerance to variations in these factors.

Sagitta minima (Grassi 1881) is characteristic of mixed waters along continental shelf regions (Alvariño 1965). Owre (1960) reported *S. minima* as being eurythermic. In this particular case, it was found to be third in abundance. It was present in oceanic and neritic samples (Figure 5) where its high abundance coincided with temperatures of 22-25°C and salinity values of 36.2-36.5‰.

Sagitta serratodentata (Krohn 1853) is oceanic, epiplanktonic and characteristic of tropical and subtropical Atlantic waters (Alvariño 1965; McLelland 1989). In the
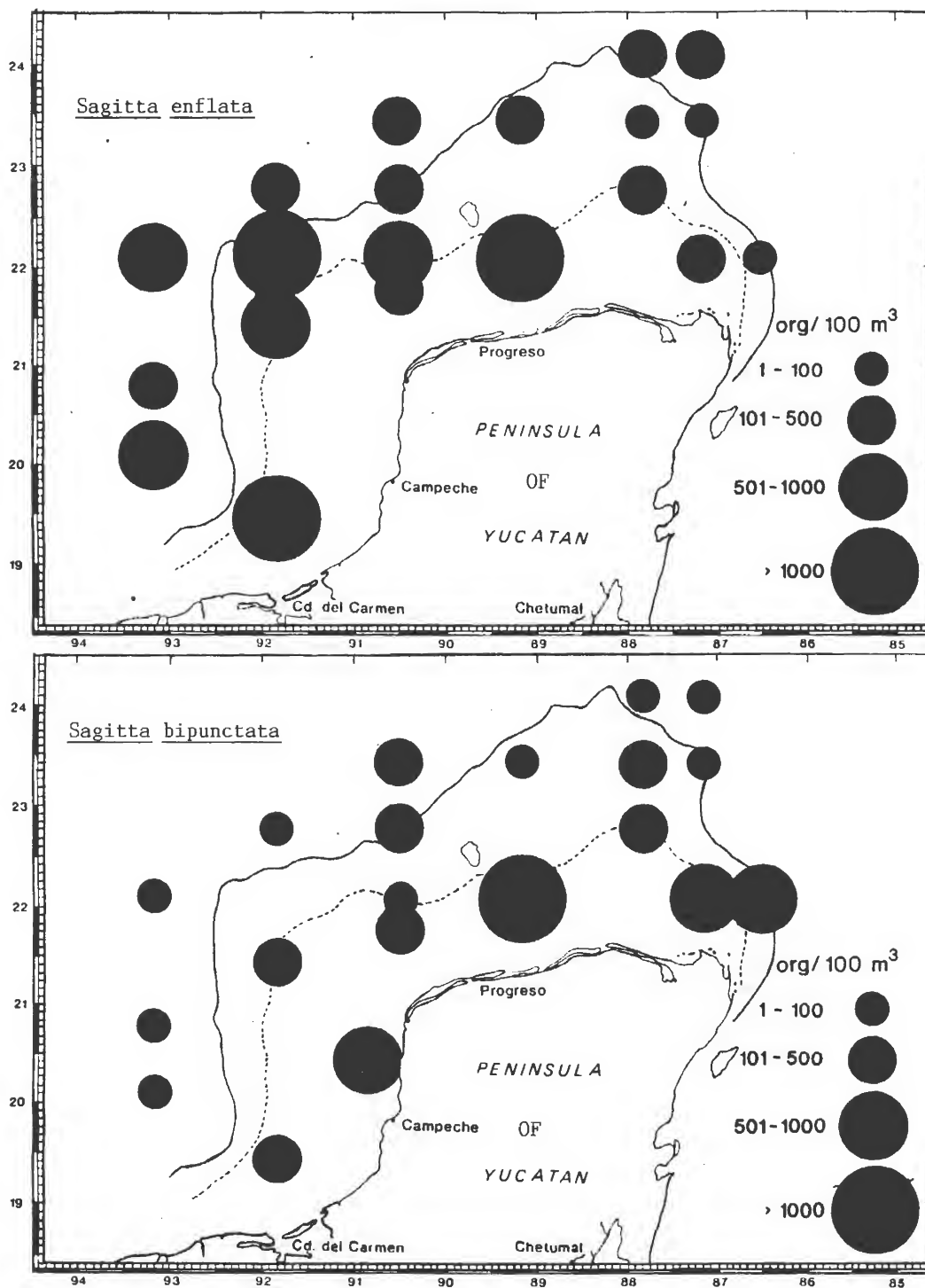
Figure 4. Abundance of *Sagitta enflata* and *S. bipunctata*. Yucatan Shelf, Mexico, May 1986.
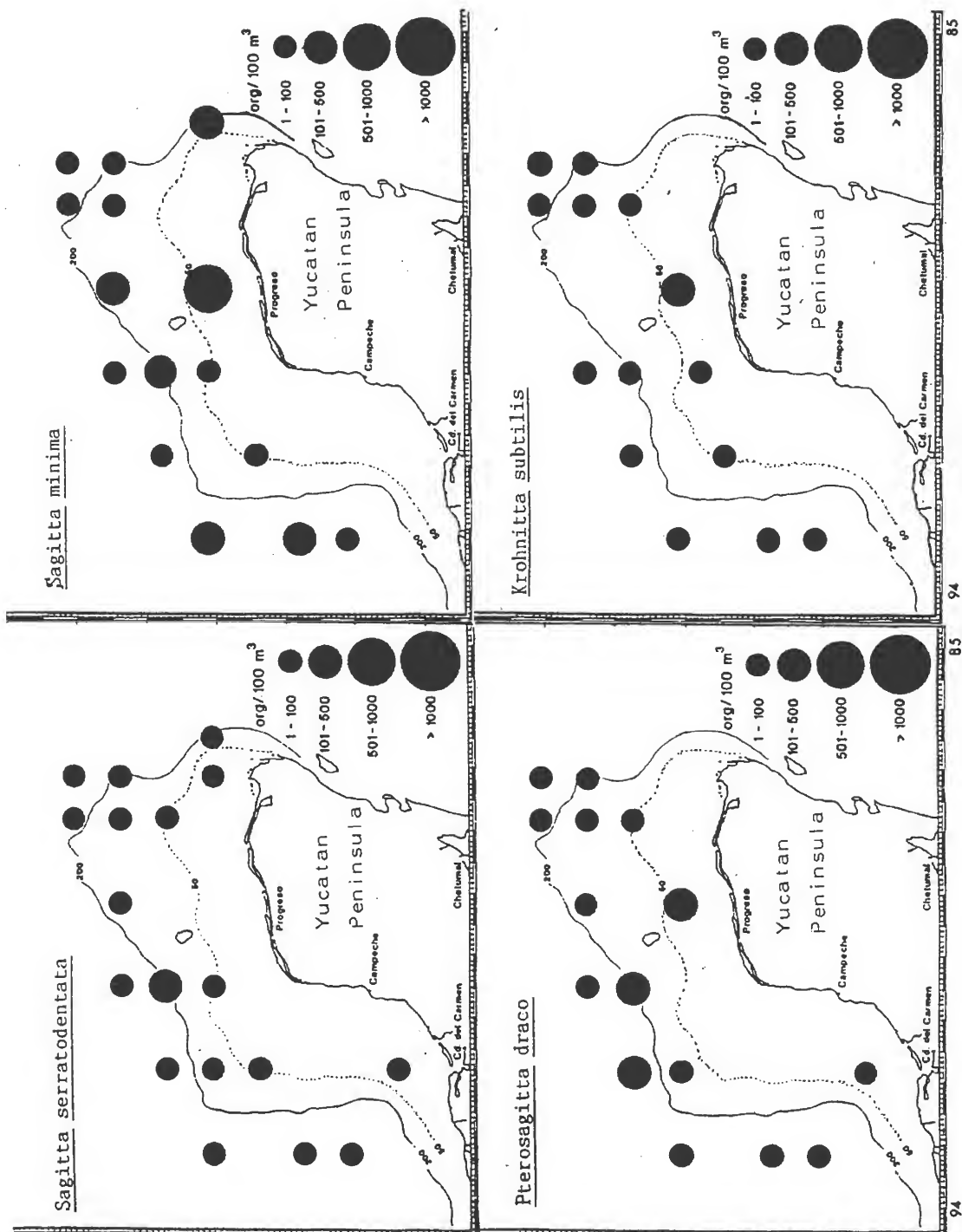
Figure 5. Abundance of *Sagitta serratodentata*, *S. minima*, *Pterosagitta draco* and *Krohnitta subtilis*. Yucatan Shelf, Mexico. May 1986.
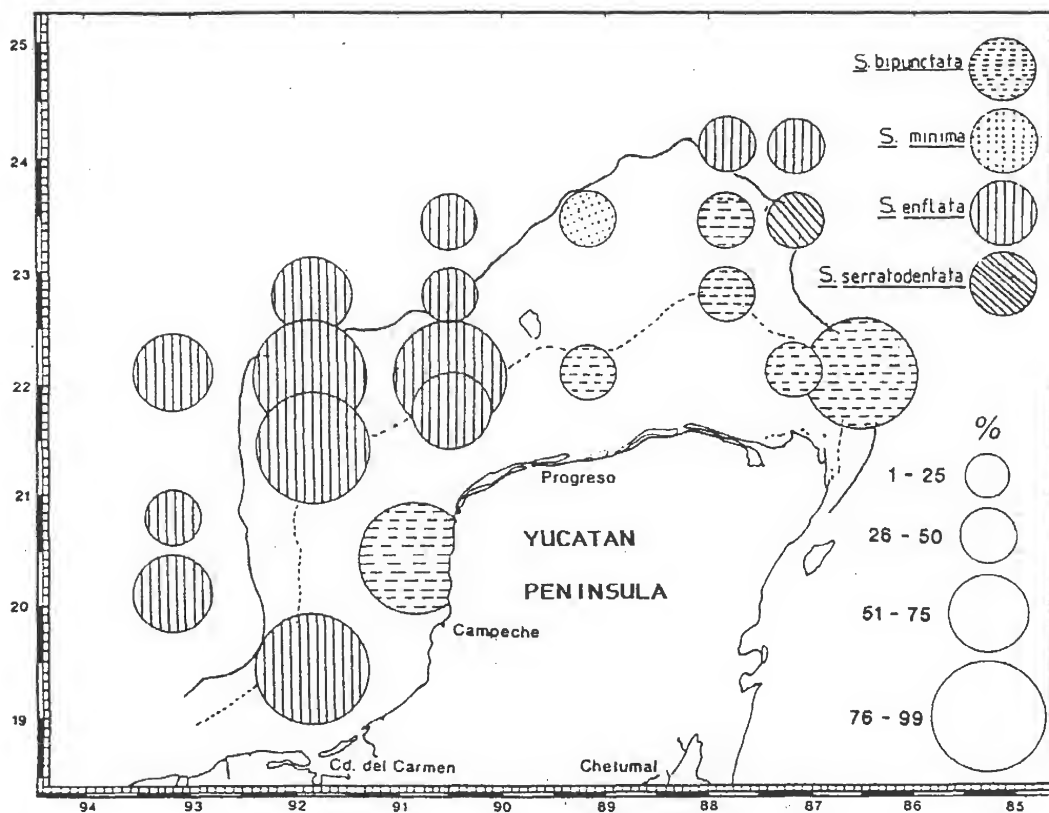
Figure 6. Relative abundance of the most important species at each station. Yucatan Shelf, Mexico. May 1986.

study area, *S. serratodentata* had a middle abundance (1024 orgs./100m³) and was distributed from the 50 m isobath to the oceanic region (Figure 5). However, it has been reported throughout the Gulf of Mexico and the Caribbean Sea as among the most abundant species (Suárez-Caabro 1955; Colman 1959; Owre 1960; Furnestin 1965; Rivero-Beltrán 1975; Michel and Foyo 1976).

Pterosagitta draco (Krohn 1853) is oceanic and lower epiplanktonic (Suárez-Caabro 1955; Owre 1960; Alvariño 1965; McLelland 1989). It is reported as abundant north of Cuba and in the Florida Current (Suárez-Caabro 1955; Owre 1960). In this study, *P. draco* showed an affinity for the oceanic environment (Figure 5) and was generally low in abundance (1-100 orgs./100m³).

Krohnitta subtilis (Grassi 1881) is oceanic and cosmopolitan in tropical and subtropical waters (Suárez-Caabro 1955; Owre 1960; Alvariño 1964, 1965; McLelland 1989). *Krohnitta subtilis* was low in abundance in the study area (1 to 100 orgs./100m³); its distribution corresponded to that reported by these authors (Figure 5).

Sagitta hexaptera (d'Orbigny 1843) oceanic and cosmopolitan in tropical and subtropical waters (Suárez-Caabro 1955; Owre 1960; Alvariño 1965; McLelland 1989). It was low in abundance in the study area, with a strong oceanic tendency in its distribution.

Sagitta friderici (Ritter-Zahony 1911) is neritic and epiplanktonic in the Atlantic Ocean and adjacent seas (Faure 1952; Colman 1959; Heydorn 1959; Alvariño 1965; Michel and Foyo 1976; McLelland 1984, 1989) and associated with coastal lagoons (Laguarda-Figueras 1967; Rivero-Beltrán 1975; López-Cano 1987) in the Gulf of Mexico and in the Caribbean Sea, although scarcely represented. *S. friderici* was found at only one station in the study area IV-70, located to the northeast of the peninsula above the 50 m isobath where salinity was 36.3°/₀₀ and temperature ranged from 24 to 25°C.

Krohnitta pacifica (Aida 1897) is semi-neritic, epiplanktonic, cosmopolitan in tropical and subtropical seas (McLelland 1989) and common in areas of mixing water masses. *Krohnitta pacifica* was present at two stations
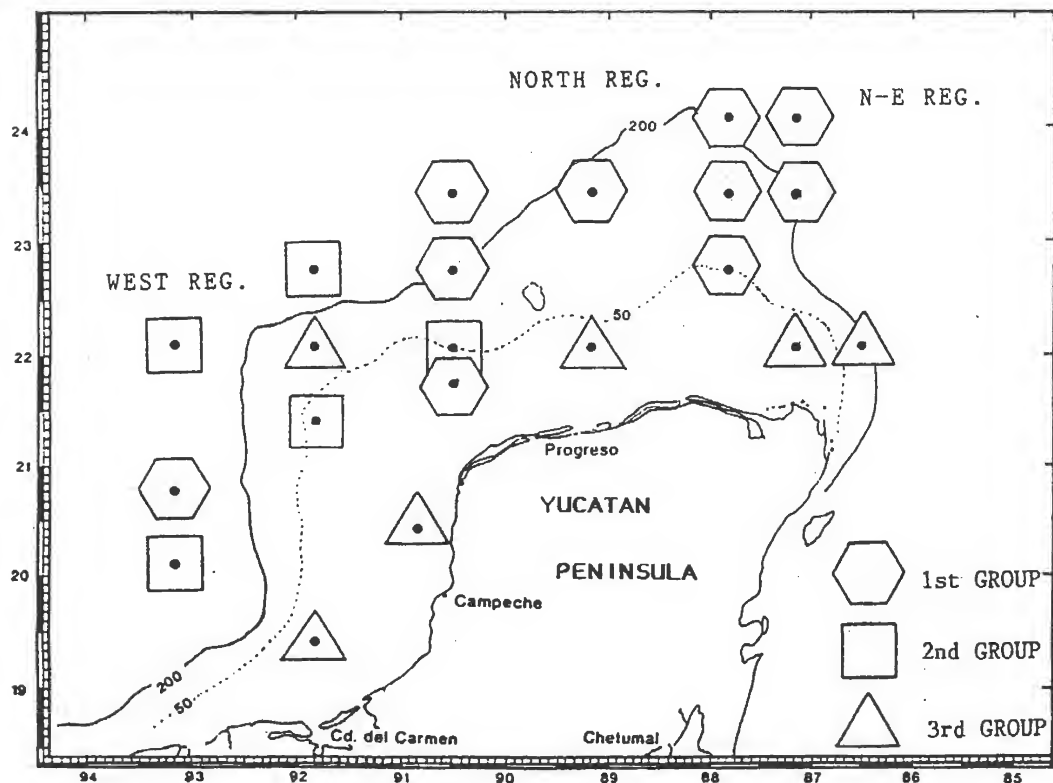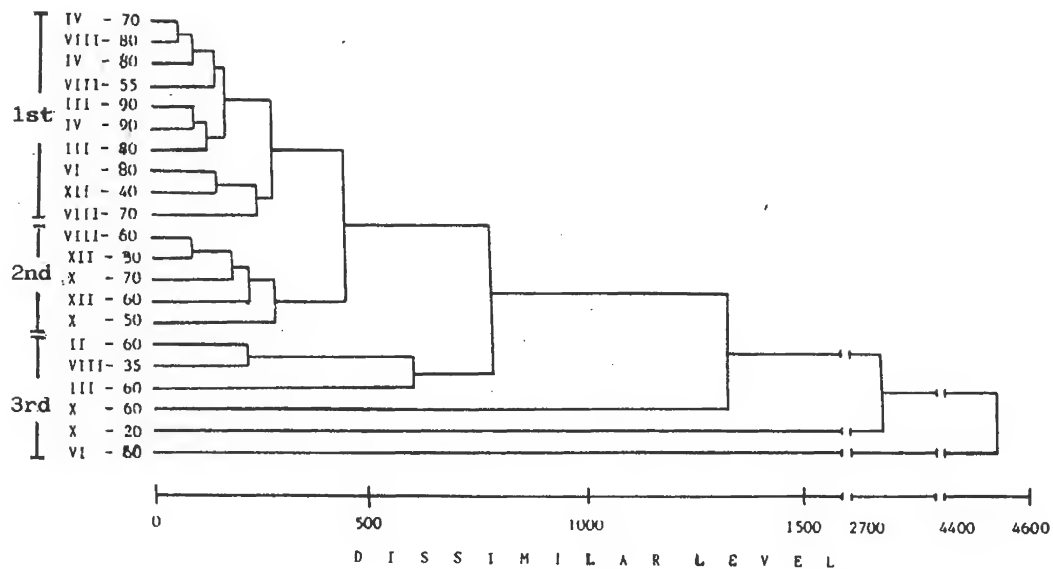
Figure 7. Classification and geographic location of station groups formed according to Euclidian distance. Yucatan Shelf, Mexico. May 1986.

in the northern part of the peninsula near the slope (200 m isobath) where salinity ranged from 36.3 to 36.4 ‰ and temperature was 25°C. These data agree with those reported by Owre (1960) in the strait of Florida, by Pierce and Wass (1962) for the Florida Current and by Michel and Foyo (1976) for the Caribbean Sea.

According to the distribution pattern for these species, three regions can be distinguished (Figure 6): 1) A shallow near-coastal region that surrounds the Peninsula in its northeastern and western side, where *Sagitta bipunctata* predominates. 2) An oceanic province located off the western side of the Peninsula, where *S. enflata* is the dominant species, and 3) An oceanic region located to the northeast of the Peninsula where specific diversity is higher and no particular species was found to be predominant.

This distribution pattern is confirmed, in general terms, by classification and ordination analysis. The Euclidian Distance analysis identified three diferent groups of species according to their spatial distribution (Figure 7). Those with higher similarity were found in the north and northeast sides of the Peninsula where temperature ranged from 25 to 27°C and salinity was 36.5‰. Here the abundance of chaetognaths was low, the specific richness was high and there was not a dominant species. This group included *Sagitta minima, S. serratodentata, S. enflata* and *S. bipunctata*. The samples in the second group were located in the northwest and west side of the Peninsula, with high temperature (25°C) and salinity (36.3-36.6‰). In these samples the abundance of chaetognaths was higher

and the predominant species was *S. enflata*. Finally, a third group is formed by two groups of samples showing high abundance: *S. bipunctata* was the dominant species along the shallow waters (<50 m) characterized by variable temperature (22-27°C) and salinity (36.4-37.0‰) values, whereas *S. enflata* was predominant at the west side of the shelf, with salinity of 36.4-36.6‰ and temperature of 25-26°C.

Finally, the groups of samples obtained from classification and ordination analysis coincided, in broad terms, with the three regions based on environmental features: (a) Northeast region, where temperature was high, salinity and abundance were low, and *Sagitta minima, S. serratodentata* and *S. bipunctata* predominated; (b) West region, where salinity, temperature and abundance were high and the most important species was *S. enflata*; and (c) North region, characterized by low values of salinity and temperature, high chaetognath abundance and *S. bipunctata* as the predominant species.

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Identification, Distribution, and Aspects of the Biology of Ten Anthuridean Isopod Species from the Shallow Continental Shelf of the U.S. Gulf and East Coast

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IDENTIFICATION, DISTRIBUTION, AND ASPECTS OF THE BIOLOGY OF TEN ANTHURIDEAN ISOPOD SPECIES FROM THE SHALLOW CONTINENTAL SHELF OF THE U.S. GULF AND EAST COAST

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ABSTRACT With the aim of easing identification of continental shelf isopods, ten species of anthurideans, viz. *Amakusanthura magnifica, Amakusanthura signata, Cyathura burbancki, Ptilanthura colpos, Ptilanthura tenuis, Hyssura bacescui, Kupellonura formosa, Neohyssura irpex, Xenanthura brevitelson,* and *Accalathura crenulata*, are given brief diagnoses. A map showing the distribution of records, line figures illustrating diagnostic features, and a key to families, genera, and species are also provided.

INTRODUCTION

While it may seem quirky to deal with only the anthuridean isopod species from among all the records of isopods from the continental shelf of the east coast of the United States, there are cogent reasons for doing so. The ten anthurideans all have a similar habitus, i.e. an elongate and slender body form, and are sometimes difficult to distinguish. Some of the species are extremely abundant and constitute a major element of the infauna of the continental shelf, where they are detritivores and scavengers. Many of the anthurideans are protogynous hermaphrodites and display unusual sex ratios and reproductive strategies that in part explain their success in this habitat. Much of the material reported here comes from Bureau of Land Management/Minerals Management Service (BLM/MMS) surveys, and is deposited in the National Museum of Natural History. Additional records from the NMNH collections have been used.

For each of these species, a map of occurrences is provided, along with line drawings of the animals having diagnostic features emphasized by arrows, as an aid to identification. The original description of the species is referenced, with a brief (and not necessarily complete) diagnosis that emphasizes the most useful features for distinguishing the species. In several cases, the male cephalon with its elongate antennules is illustrated. Reference is made to males and premales; the latter differ from mature males in that the elongate antennules do not possess dense whorls of aesthetascs. Often the copulatory stylet of premales is not as developed as in the mature males. Some information on sex ratios, reproductive status, and depth distribution, is also given. Appendix 1 lists station data for the ten species.

Key to the Anthuridea of the shallow continental shelf of the eastern U.S.A.

1. Pleonites 1-5 free, length of each pleonite at least half of width, sometimes longer .... Hyssuridae 2
   Pleonites free but length much less than width, or pleonites fused 6
2. Telson shorter than, and hidden by, subcircular uropodal exopods........................*Xenanthura brevitelson*
   Telson not short, not completely hidden by uropodal exopods...3
3. Uropodal exopods armed with 3 large teeth on mesial margin..*Neohyssura irpex*
   Uropodal exopods lacking teeth 4
4. Lateral margins of telson serrate; Telson apically narrowly rounded..........................*Kupellonura formosa*
   Lateral margins of telson entire; Telson apically with short,central,truncate,offset region .... *Hyssura*......5
5. Lateral margins of telson roughly parallel ....
   ....*Hyssura bacescui*
   Lateral margins of telson convex...........*[Hyssura vimsae* (Kensley 1978); deep shelf/slope species off New Jersey and Virginia, 350-460 m]
6. Mouthparts slender, styliform, adapted for piercing and sucking...Paranthuridae........*Accalathura crenulata*
   Mouthparts not styliform, adapted for cutting ....
   ....Anthuridae.................7
7. Telson having 3 longitudinal ridges dorsally ....
   ....*Ptilanthura*............8
   Telson lacking dorsal longitudinal ridges 9
8. Telson roughly parallel-sided, apically truncate ....
   ....*Ptilanthura colpos*
   Lateral margins of telson convex, apically broadly rounded..*Ptilanthura tenuis*
9. Pleonites demarked by dorsal lines or folds; that between pleonites 4 and 5 incomplete ....
   .... *Amakusanthura* 10
   Pleonites 1-5 completely fused, lacking dorsal lines or folds..*Cyathura burbancki*

10. Telson having dorsal raised ridge anteriorly, ridge widening posteriorly; uropodal exopod with weak laterodistal notch...................*Amakusanthura magnifica*
Telson dorsally flat; uropodal exopod with strong laterodistal notch..................*Amakusanthura signata*

Family Anthuridae Leach 1814

Diagnosis. Mouthparts adapted for cutting and tearing. Pleonites 1-5 fused, pleonite 6 often indicated dorsally, or fused with telson. Exopod of pleopod 1 operculiform, covering rest of pleopods. Pair of basal statocysts present on telson.

Amakusanthura magnifica (Menzies and Frankenberg 1966)   (Figures 1 A, B, 2)
Apanthura magnifica Menzies and Frankenberg 1966:40, Figure 17.

Material. 59 ♂, 1544 non-ovigerous ♀ and juveniles. Occurrences: 338 stations, depth range 1-206 m, mean depth for 338 stations - 64 m.
Diagnosis. Small well pigmented eyes present. Pleonites 4 and 5 dorsally incompletely separated. Uropodal exopod with slight notch in lateral margin. Telson with broad dorsal raised area in posterior half, narrowing anteriorly to median rounded ridge. Antennule in male reaching posteriorly to pereonite 2.

Amakusanthura signata (Menzies and Glynn 1968)
(Figure 1 C, D, 3)
Apanthura signata Menzies and Glynn 1968:28, Figure 10.

Material. 6 ♂ and pre-♂, 114 non-ovigerous ♀. Occurrences: 35 stations, depth range 1-159 m, mean depth for 35 stations - 39 m.
Diagnosis. Small well pigmented eyes present. Pleonites 4 and 5 dorsally incompletely separated. Uropodal exopod with strong notch in distolateral margin. Telson dorsally flat, posterior margin with slight terminal notch. Antennule in male reaching posteriorly to pereonite 2.

Cyathura burbancki Frankenberg 1965
(Figure 1 E, F, 4)
Cyathura burbancki Frankenberg 1965:206, Figures. 1-3.

Material. 11 ♂, 5 ovigerous ♀, 25 non-ovigerous ♀. Occurrences: 13 stations, depth range 11-225 m, mean depth from 13 stations - 32 m.
Diagnosis. Eyes small, well pigmented. Antennule in male with distal brush of aesthetascs. Pleonites 1-5 fused, shorter than pereonite 7; pleonite 6 demarked

dorsally. Telson gently tapering, apex narrowly rounded. Distinguished from estuarine/shallow-water *C. polita* by pleonite 6 being dorsally demarked (fused with telson in *C. polita*) (see Frankenburg 1965 Table 1 for differences).

Ptilanthura colpos Kensley 1996
(Figure 5 A, 6)
Ptilanthura colpos Kensley 1996:

Material. 31 non-ovigerous ♀, 7 manca. Occurrences: 26 stations, depth range 14-88 m, mean depth for 26 stations - 38 m.
Diagnosis. Cephalon longer than broad. Pereonite 1 anterodorsal emargination straight. Telson widest at midlength, having rounded median longitudinal ridge and two shorter lateral ridges in posterior half, almost parallel-sided, posterior margin truncate.

Ptilanthura tenuis Harger 1878
(Figure 5 B, C, D, 7)
Ptilanthura tenuis Harger 1878:377.

Material. 31 ♂ and pre-♂, 438 non-ovigerous ♀, 100 manca. Occurrences: 206 stations, depth range Intertidal - 339 m, mean depth for 206 stations - 71 m.
Diagnosis. Cephalon as broad or broader than long. Pereonite 1 anterior margin with triangular emargination. Telson widest in posterior half, having rounded median longitudinal ridge and two shorter lateral ridges in posterior half; posterior margin rounded. Primary male having 10 articles in antennular flagellum, latter rarely reaching posterior margin of pereonite 1. Secondary male having 22 articles in antennular flagellum, latter reaching well beyond pereonite 1.

Family Hyssuridae Wägele 1981

Diagnosis. Mouthparts adapted for cutting and tearing. Pereopods 1-3 subchelate, similar. Pleonites 1-6 free, large, often as long as wide. Pleopod 1 similar to following pleopods, not operculiform. Telson lacking statocysts.

Hyssura bacescui (George and Negoescu-Vladescu 1982)
(Figure 5 E, 8)
Ocsanthura bacescui George and Negoescu-Vladescu 1982:97, Figures. 1-3.

Material. 7 non-ovigerous ♀. Occurrences: 6 stations, depth range 37-445 m, mean depth for 6 stations - 230 m.
Diagnosis. Eyes lacking. Uropodal exopod distally
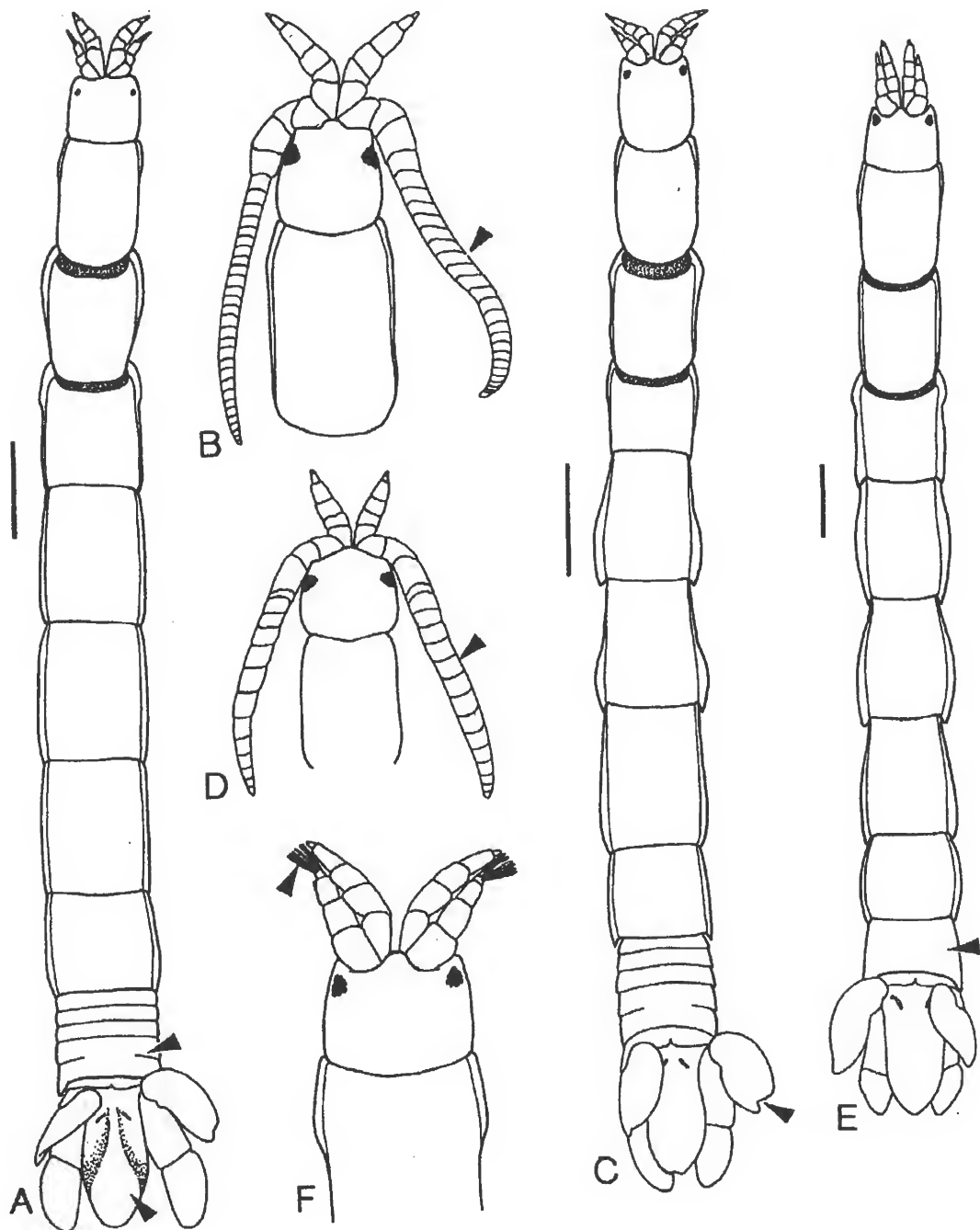
Figure 1. A, *Amakusanthura magnifica* ♀, scale = 1 mm; B, *Amakusanthura magnifica*, cephalon and pereonite 1 ♂, aesthetascs omitted; C, *Amakusanthura signata* ♀, scale = 0.5 mm; D, *Amakusanthura signata*, cephalon and pereonite 1 ♂, aesthetascs omitted; E, *Cyathura burbancki* ♀, scale = 1 mm; F, *Cyathura burbancki* ♂, cephalon and pereonite 1.
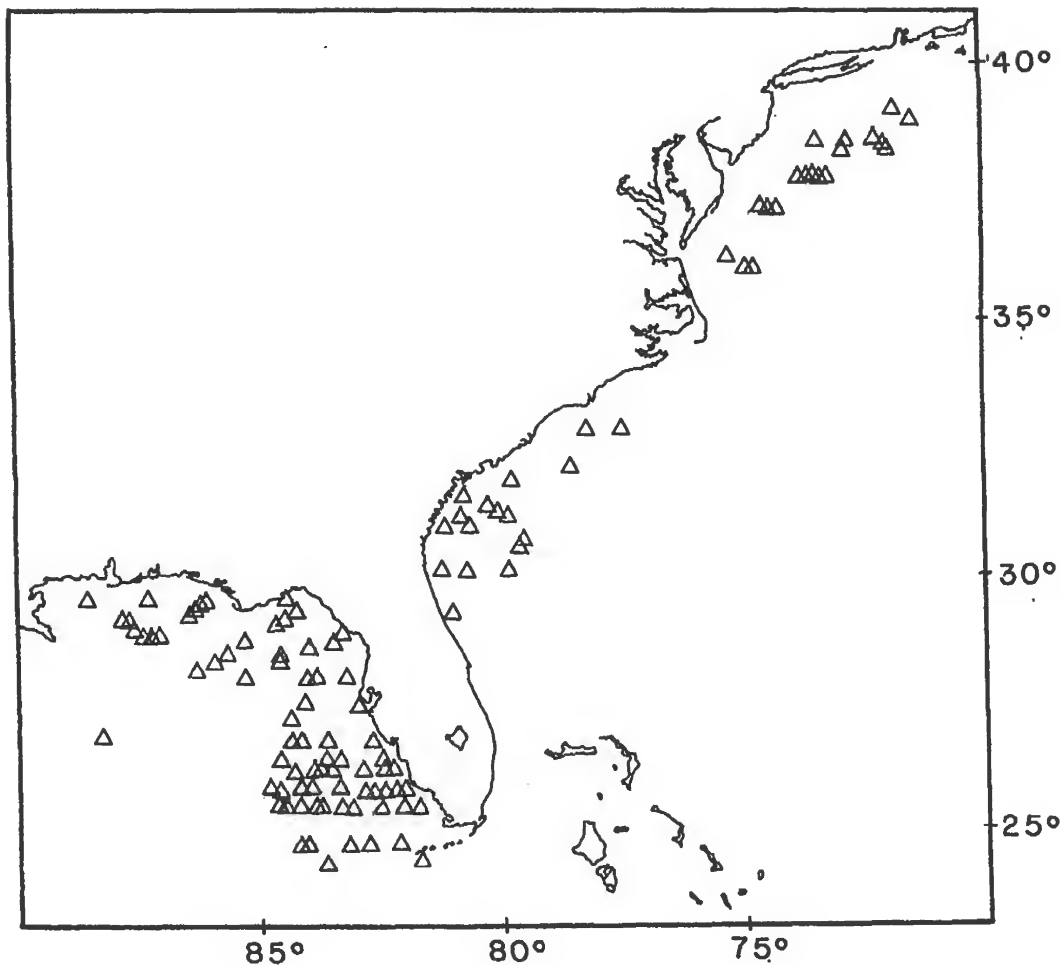
Figure 2. *Amakusanthura magnifica* occurrences.

broad, rounded; endopod about twice longer than wide, distally rounded. Telson parallel-sided, posterior margin with short central truncate region offset from broad main body of telson.

Kupellonura formosa (Menzies and Frankenberg 1966)
(Figure 9 A, B, C, 10)
Panathura formosa Menzies and Frankenburg 1966:39, Figure 16.

Material. 13 ♂ and pre-♂, 94 non-ovigerous ♀. Occurrences : 26 stations, depth range 14-159 m, mean depth for 26 stations - 63 m.

Diagnosis. Cephalon having small pigmented eyes, larger in male than in female. Uropodal exopod broad, with lateral margin distally broadly emarginate. Telson with posterolateral margins finely serrate; apically narrowly rounded.

Neohyssura irpex (Menzies and Frankenberg 1966)
(Figure 9 D, E, F, 11)
Horoloanthura irpex Menzies and Frankenberg 1966:42, Figure 18.

Material. 9 ♂ and pre-♂, 484 non-ovigerous ♀ and juveniles. Occurrences: 212 stations, depth range 10-460 m, mean depth for 212 stations - 70 m.

280
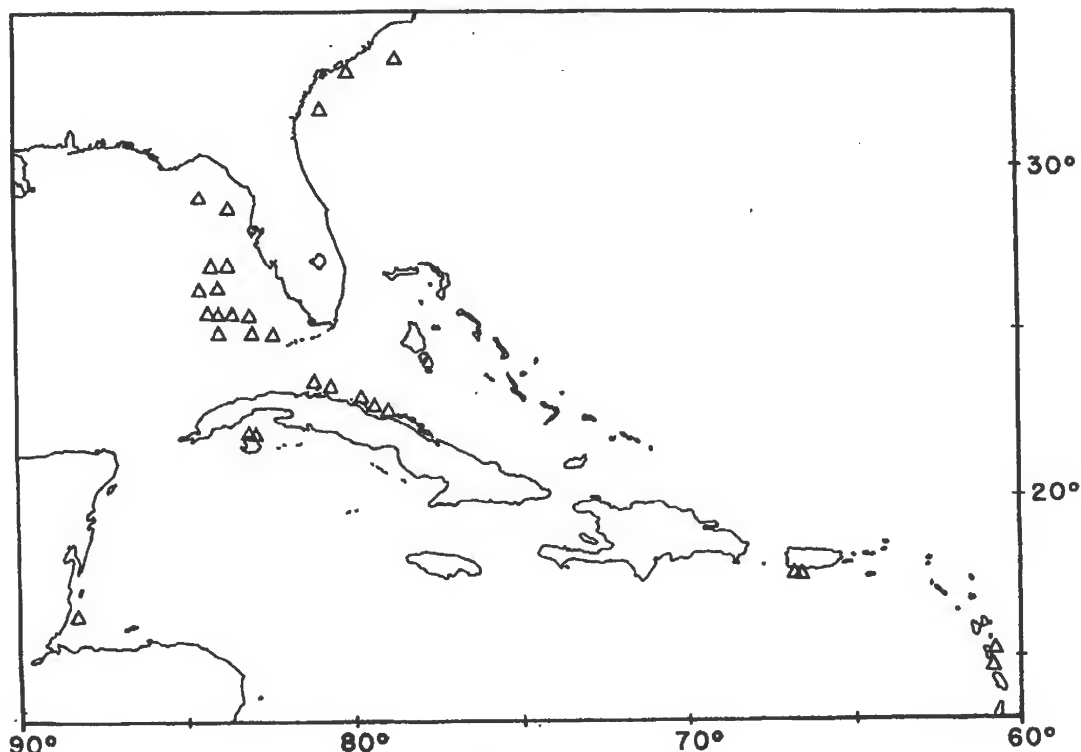
Figure 3. *Amakusanthura signata* occurrences.

Diagnosis. Eyes lacking. Pereopods 1-3 subchelate, having expanded propodi. Uropodal exopod having 3 prominent teeth on mesial margin. Telson tapering to narrow truncate apex.

Xenanthura brevitelson Barnard 1925
(Figure 12 A, B, C, 13)
Xenanthura brevitelson Barnard 1925:138, pl. 4, Figure 14.

Material. 209 ♂ and pre-♂, 2235 non-ovigerous ♀ and juveniles. Occurrences: 516 station, depth range Intertidal-180 m, mean depth for 516 stations - 58 m.

Diagnosis. Cephalon having row of 3 or 4 large ommatidia with pigment on each side. Pereopods 1-3 with propodi expanded, much broader than following pereopods. Uropodal exopods overlapping, subcircular; endopod with distomesial margin concave, bearing 3 stout setae. Telson tapering, much shorter than, and obscured by, subcircular uropodal exopods; posterior margin concave, bearing 2 stout setae.

Family Paranthuridae Menzies and Glynn 1968

Diagnosis. Mouthparts slender, styliform, adapted for piercing and sucking. Pleonites free or fused; if free, segments much shorter than wide. Telson having single basal statocyst, or lacking statocyst.

Accalathura crenulata (Richardson 1901)
(Figure 12 D, E, 14)
Calathura crenulata Richardson 1901:509.

Material. 20 ♂, 13 ovigerous ♀, 152 non-ovigerous ♀ and juveniles. Occurrences: 101 stations, depth range 1-90 m, mean depth for 101 stations, 37 m.

Diagnosis. Large well pigmented eyes present. Flagella of antennule and antenna multiarticulate. Uropodal exopod widest basally, narrowed and tapering distally; endopod ovate, short, one-third length of protopod. Telson lanciform, with single basal statocyst.

Figure 4. *Cyathura burbancki* occurrences.

Figure 5. A, *Ptilanthura colpos* ♀, scale = 1 mm; B, *Ptilanthura tenuis* ♀, scale = 1 mm; C, *Ptilanthura tenuis*, cephalon and pereonite 1, primary ♂; D, *Ptilanthura tenuis*, cephalon and pereonite 1, secondary ♂; E, *Hyssura bacescui* ♀, scale = 1 mm.
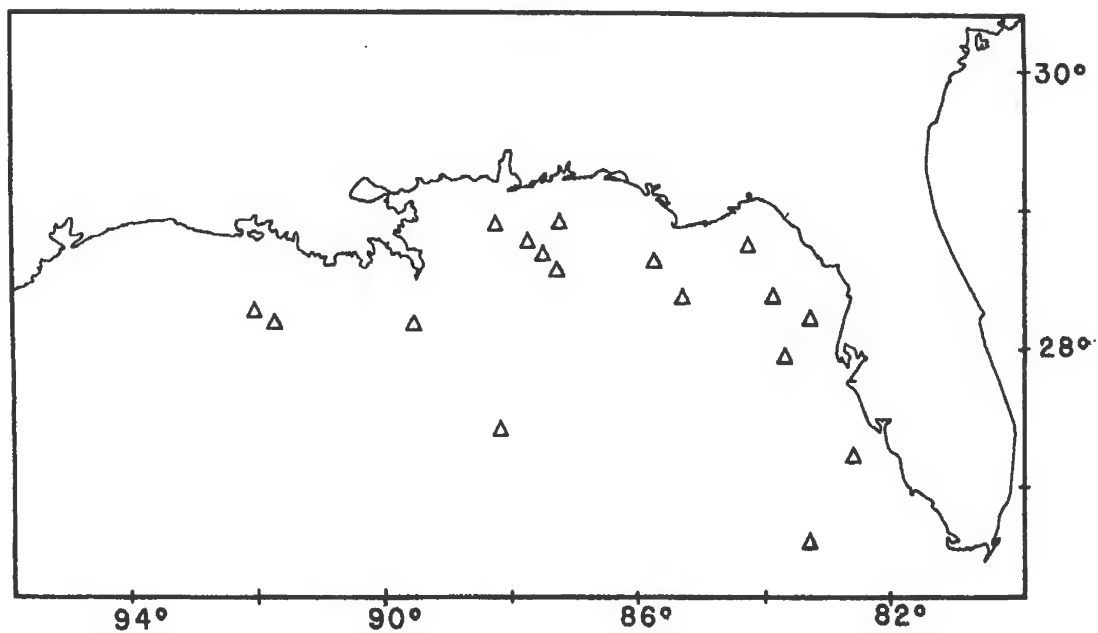
Figure 6. *Ptilanthura colpos* occurrences.
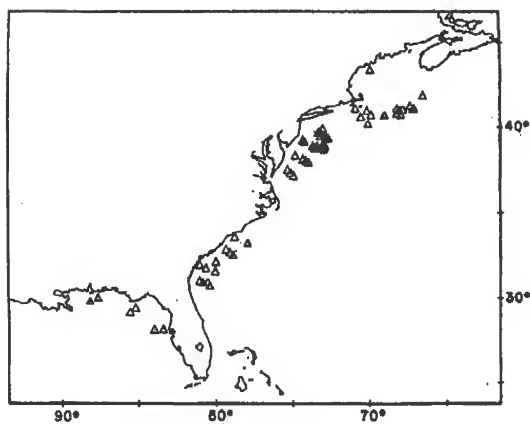
Figure 7. *Ptilanthura tenuis* occurrences.
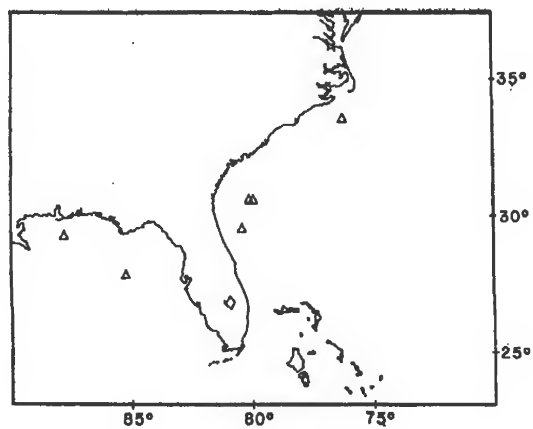
Figure 8. *Hyssura bacescui* occurrences
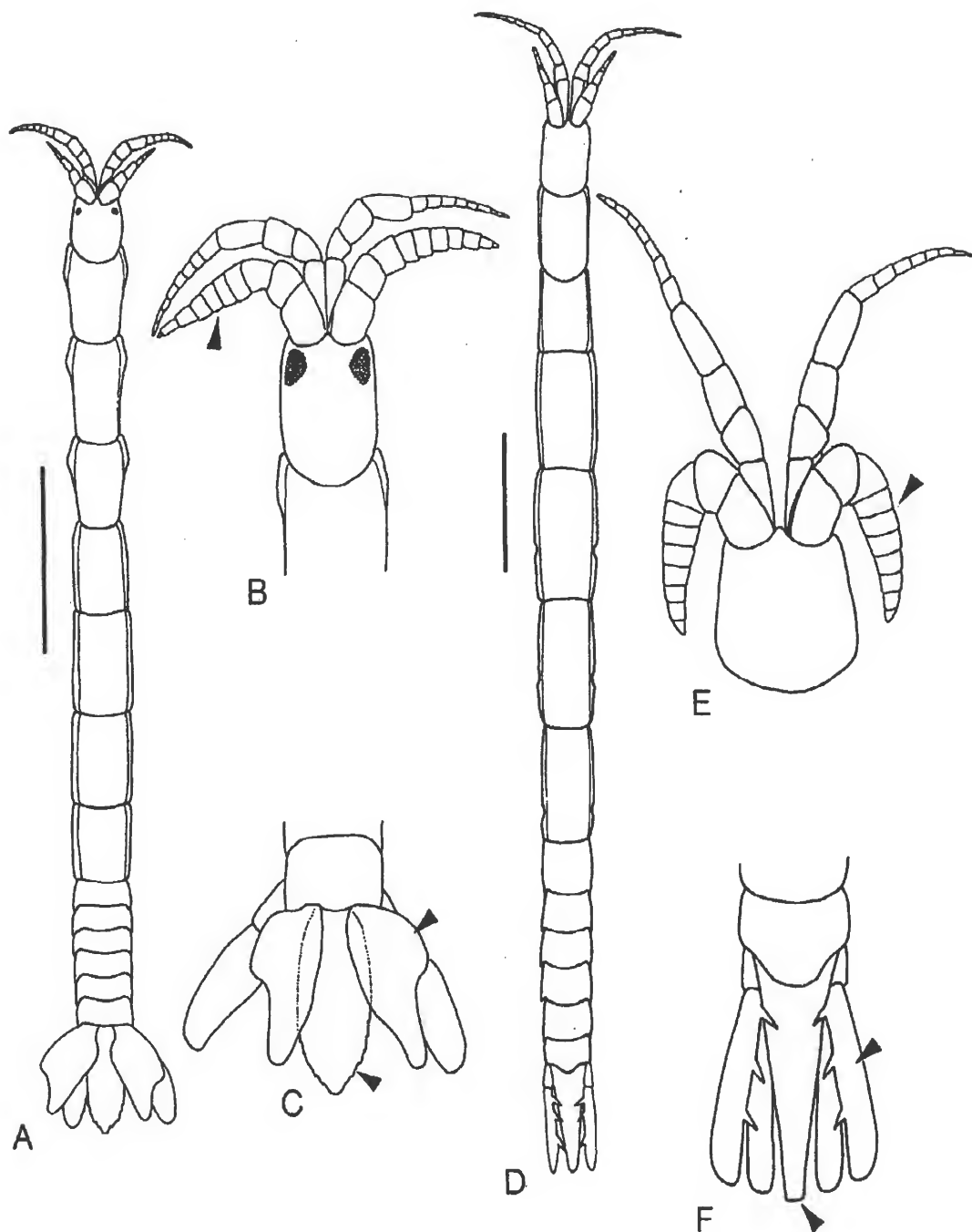
Figure 9. A, *Kupellonura formosa* ♀, scale = 1 mm; B, *Kupellonura formosa*, cephalon and pereonite 1 ♂, aesthetascs omitted; C, *Kupellonura formosa*, pleonite 6 and tail-fan; D, *Neohyssura irpex* ♀, scale = 0.5 mm; E, *Neohyssura irpex* cephalon ♂, aesthetascs omitted; F, *Neohyssura irpex*, pleonite 6 and tailfan.
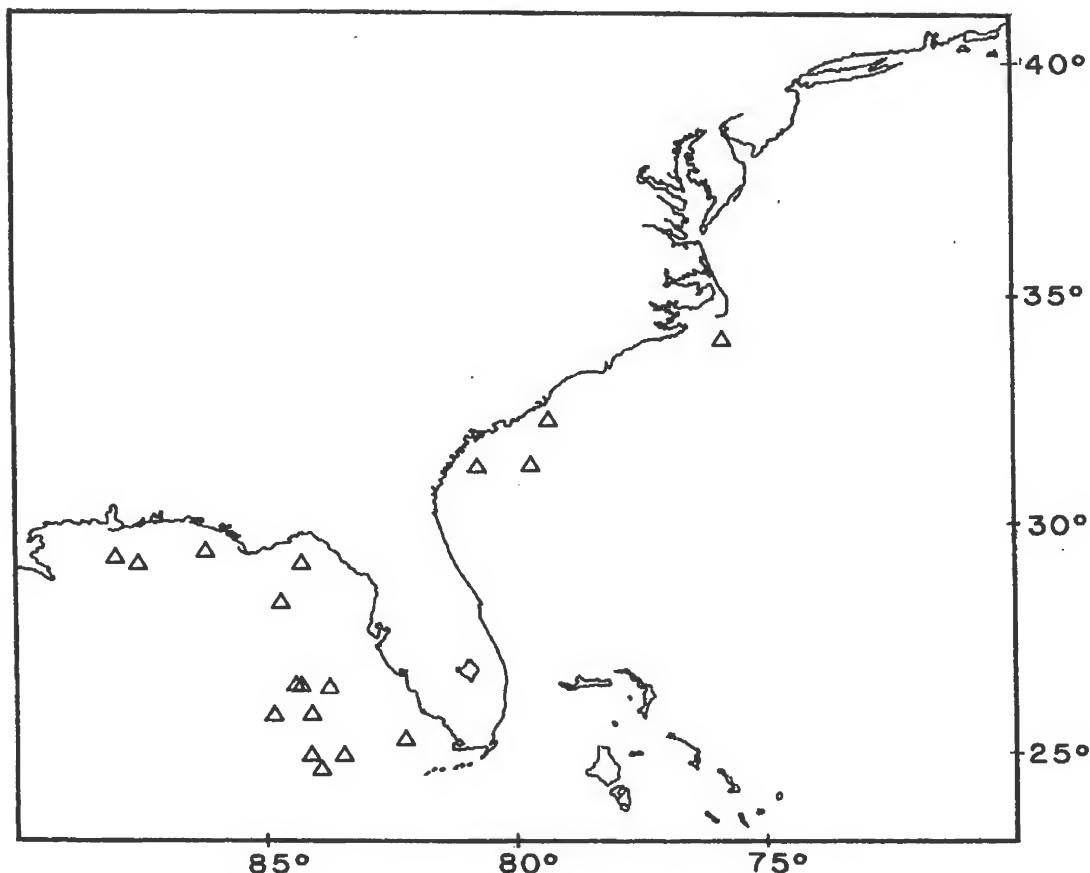
Figure 10. *Kupellonura formosa* occurrences.

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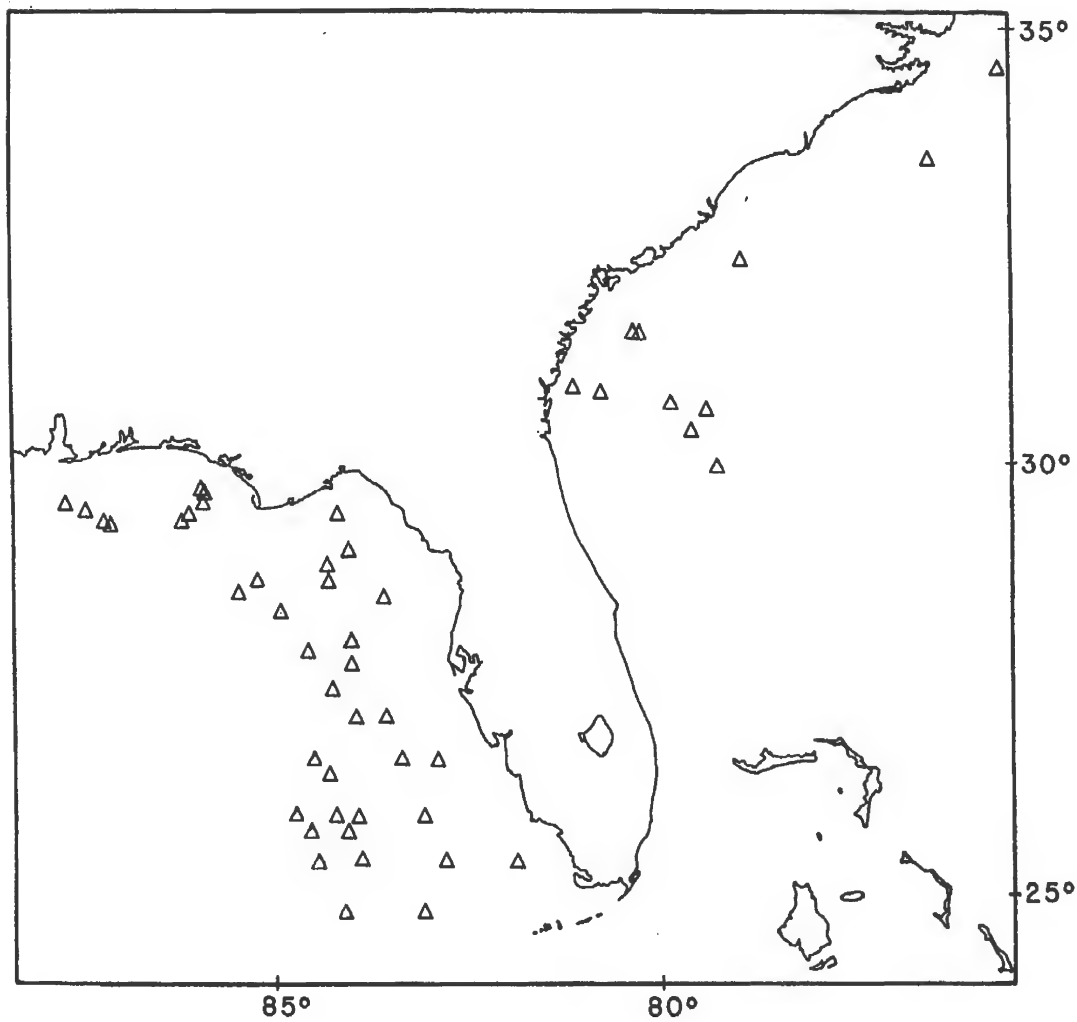
Figure 11. *Neohyssura irpex* occurrences.
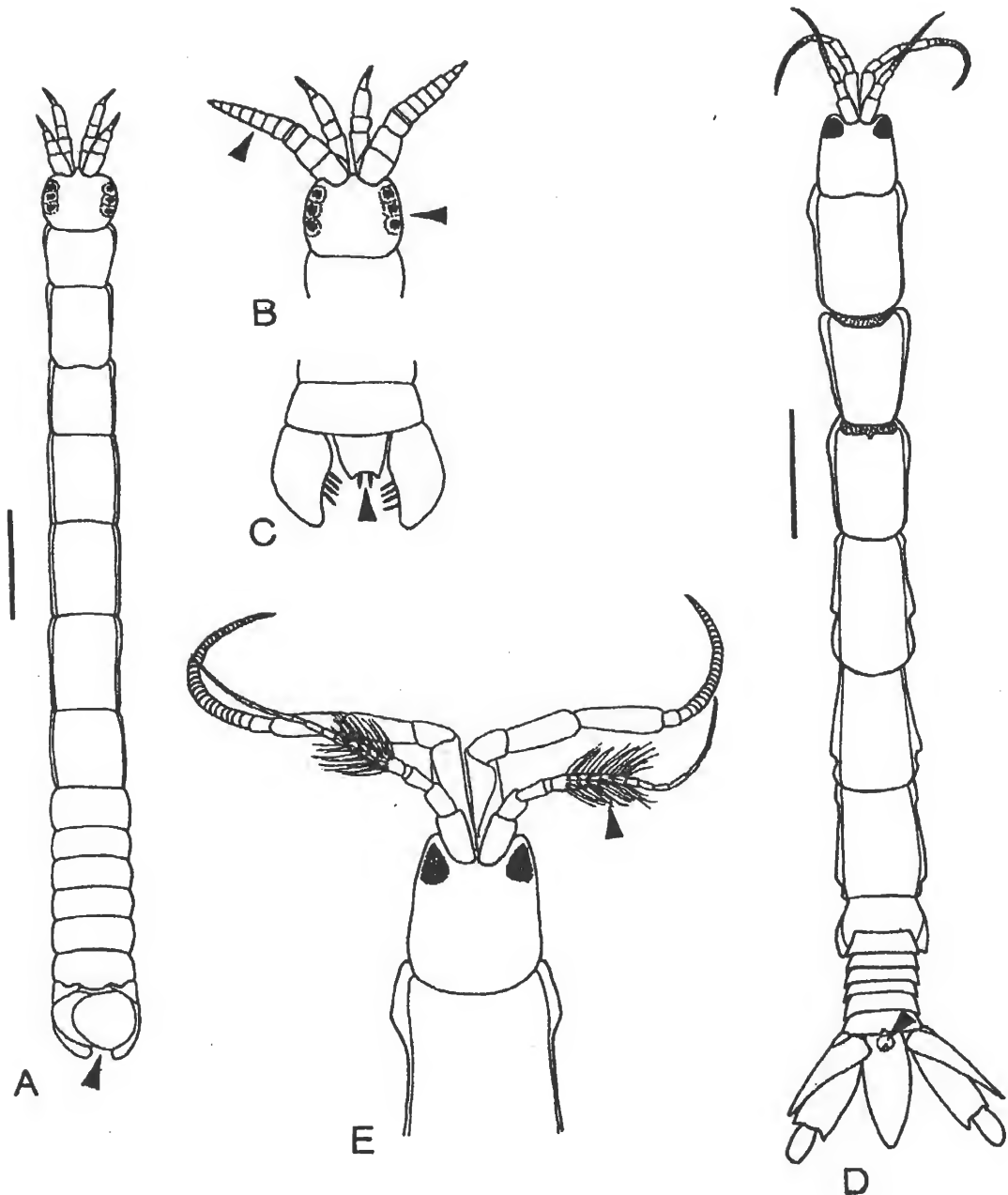
Figure 12. A, *Xenanthura brevitelson* ♀, scale = 0.5 mm; B, *Xenanthura brevitelson*, cephalon ♂; C, *Xenanthura brevitelson*, pleonite 6, telson, and uropodal endopods, uropodal exopods removed; D, *Accalathura crenulata* ♀, scale = 2 mm; E, *Accalathura crenulata*, cephalon ♂.
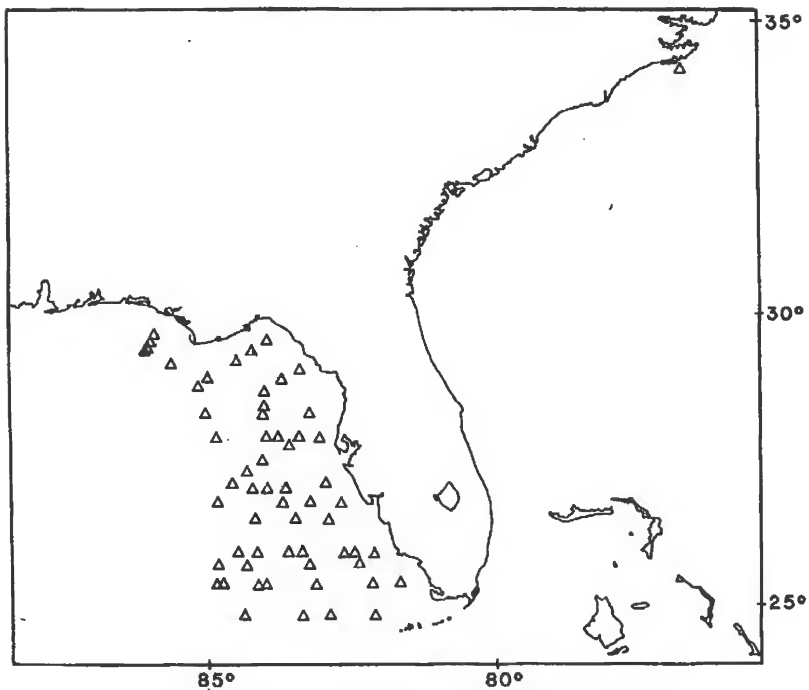
Figure 13. *Xenanthura brevitelson* occurrences.
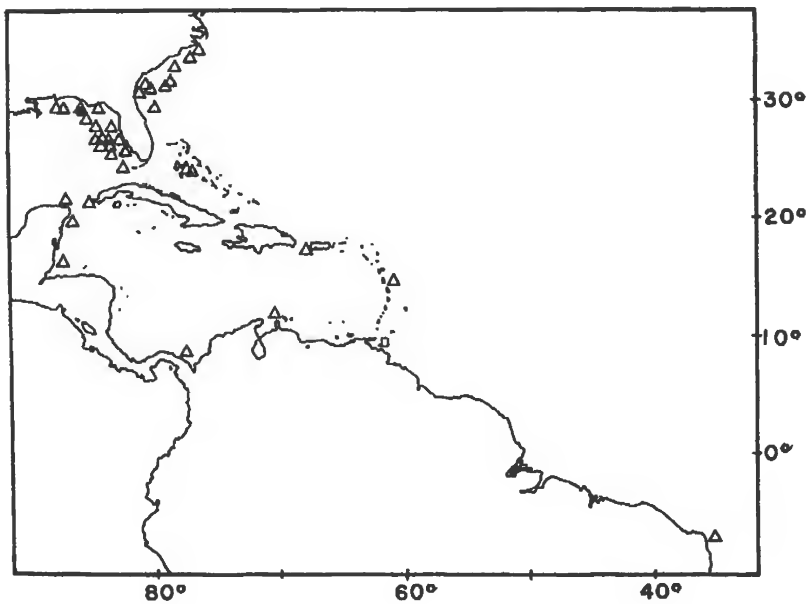
Figure 14. *Accalathura crenulata* occurrences.

APPENDIX 1. STATION DATA BY ANTHURIDEAN SPECIES.

Abbreviations: ACE - Albatross Caribbean Expedition; CABP - Central Atlantic Benchmark Program; CGPS - Central Gulf Platform Study; K+S - Kensley & Schotte; LMRS - Living Marine Resources Study; MAFLA - Mississippi Alabama Florida Survey; M&G - Menzies & Glynn; MMS - Minerals Management Service; NEEB - New England Environmental Benchmark Program; P+R - Pilsbry & Richardson; SABP - South Atlantic Benchmark Program; S-BE - Smithsonian-Bredin Expedition; SOFLA - Southwest Florida Shelf Ecosystem Study; USFC - United States Fish Commission; USGS - United States Geological Service.

ACCALATHURA   CRENULATA

Program/Donor	Station	Latitude/Longitude	Depth (meters)	Date Collected
		08°55'--"N 077°42'--"W		-- --- ----
		12°30'--"N 069°58'--"W	43.9	-- --- ----
		16°48'--"N 088°05'--"W		12 JAN 1976
	1	16°48'--"N 088°05'--"W		17 JAN 1976
	147	16°48'--"N 088°05'--"W	3	27 APR 1977
ACE		21°50'--"N 084°57'--"W	9.15	07 MAY 1884
ACE	2363	21°35'--"N 087°05'--"W	38.41	30 JAN 1885
ALBATROSS R/V	2758	05°29'--"S 035°16'--"W	36.58	16 DEC 1887
BARTSCH, P.		24°26'--"N 077°57'--"W		09 FEB 1912
BARTSCH, P.		24°26'--"N 077°57'--"W		13 MAY 1912
CORTEZ, H.	67-21	26°24'--"N 083°22'--"W	55	13 JAN 1967
CORTEZ, H.	67-342	27°37'--"N 083°58'--"W	55	06 OCT 1967
CORTEZ, H.	67-352	26°24'--"N 083°22'--"W	55	12 OCT 1967
FISHHAWK R/V	(137) 6065	18°12'--"N 067°10'--"W	7.32-10.97	20 JAN 1899
K & S	K-DOM-21	15°14'--"N 061°19'--"W	3-5	18 NOV 1992
KENSLEY, B.	K-11	17°05'--"N 088°05'--"W	6.1	01 FEB 1978
KENSLEY, B.	K-12	16°50'--"N 088°05'--"W		02 FEB 1978
LMRS	IS02	31°23'36"N 080°53'12"W	18	15 NOV 1981
LMRS	MS03	30°54'18"N 080°36'12"W	35	04 SEP 1980
LMRS	MS06	32°49'18"N 078°39'54"W	33	08 AUG 1981
LMRS	MS06	32°49'24"N 078°39'48"W	34	27 JUL 1981
LMRS	MS06	32°49'30"N 078°39'48"W	34	25 MAY 1981
LMRS	OS01	31°32'00"N 079°44'18"W	57	29 OCT 1981
LMRS	OS01	31°32'06"N 079°44'12"W	58	03 MAY 1981
LMRS	OS02	31°07'18"N 079°55'06"W	50	11 SEP 1980
LMRS	OS02	31°08'00"N 079°54'54"W	55	11 SEP 1980
LMRS	OS03	30°37'00"N 081°10'42"W	22	04 AUG 1980
MAFLA	2101	26°25'00"N 081°15'09"W	11	--- NOV 1977
MAFLA	2103	26°25'00"N 082°58'00"W	33	--- JUL 1976
MAFLA	2104	26°25'00"N 083°23'01"W	53	--- SEP 1975
MAFLA	2105	26°45'00"N 083°49'58"W	90	--- --- --- ----
MAFLA	2210	27°57'29"N 083°42'29"W	37	--- JUL 1976
MAFLA	2211	27°56'30"N 083°53'00"W	43	--- JAN 1977
MAFLA	2315	28°33'59"N 084°20'09"W	38	30 AUG 1977
MAFLA	2422	29°30'--"N 084°27'--"W	24	--- --- 1976
MAFLA	2528	29°54'59"N 086°04'58"W	37	-- JUL 1976
MAFLA	2531	29°47'59"N 086°09'29"W	45	-- SEP 1977
MAFLA	2640	29°43'29"N 087°54'30"W	35	18 JAN 1976
MAFLA	2644	29°36'12"N 087°23'30"W	75	-- --- ----
MAFLA	2747	27°24'12"N 084°07'18"W	74	--- NOV 1977

MAFLA	2748	27°37'12"N 083°53'30"W	50	--	JUL	1976
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	---	1976
MAFLA	2854	29°24'00"N 085°42'02"W	42	--	JUL	1976
P & R		24°46'--"N 077°39'--"W		--	---	1875
SABP	7D	29°34'06"N 080°21'51"W	44	27	NOV	1977
SABP	IS03	30°37'00"N 081°10'42"W	20	--	---	----
SABP	IS05	34°23'06"N 076°34'12"W	20	--	---	----
SABP	MS04	33°32'12"N 077°24'30"W	29	--	---	----
SABP	MS04	33°32'18"N 077°25'00"W	30	--	---	----
S-BE	48-60	20°25'--"N 086°55'--"W		08	APR	1960
SOFLA	04	26°45'49"N 083°32'07"W	52.2	--	---	----
SOFLA	22	25°17'11"N 083°02'04"W	52.2	--	---	----
SOFLA	40	26°46'45"N 082°30'25"W	18	--	---	----
SOFLA	48	25°45'58"N 082°01'08"W	18	--	---	----
SOFLA	54	C 24°49'55"N 081°50'33"W	17	--	---	1974
TALISMAN R/V		16°50'--"N 025°00'--"W	10-30	--	---	1883

AMAKUSANTHURA MAGNIFICA

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
CABP	A1	39°14'24"N 072°47'18"W	90	12	FEB	1977
CABP	A2	39°21'36"N 072°31'18"W	129	07	AUG	1977
CABP	A2	39°22'12"N 072°31'00"W	127	05	MAR	1976
CABP	A3	39°16'18"N 072°29'18"W	149	07	AUG	1977
CABP	A3	39°16'30"N 072°29'36"W	136	22	AUG	1976
CABP	A3	39°16'30"N 072°29'48"W	136	12	FEB	1977
CABP	A3	39°16'30"N 072°29'48"W	139	16	NOV	1976
CABP	A4	39°14'18"N 072°26'48"W	196	23	JUN	1976
CABP	B1	39°19'18"N 073°10'12"W	63	04	NOV	1975
CABP	F1	38°43'30"N 073°13'54"W	84	20	AUG	1976
CABP	F1	38°44'18"N 073°14'36"W	86	19	JUN	1976
CABP	F1	38°45'24"N 073°16'18"W	79	09	FEB	1977
CABP	F2	38°43'42"N 073°08'30"W	113	20	AUG	1976
CABP	F2	38°44'12"N 073°09'06"W	116	11	AUG	1977
CABP	F2	38°44'12"N 073°09'18"W	112	19	JUN	1976
CABP	F2	38°44'18"N 073°09'18"W	111	12	NOV	1976
CABP	F3	38°43'36"N 073°04'00"W	153	20	AUG	1976
CABP	F3	38°43'48"N 073°04'06"W	155	10	FEB	1977
CABP	F3	38°43'54"N 073°04'06"W	162	10	AUG	1977
CABP	F4	38°44'12"N 073°02'36"W	206	10	FEB	1977
CABP	F4	38°44'18"N 073°03'06"W	184	20	JUN	1976
CABP	F4	38°44'30"N 073°03'00"W	180	10	AUG	1977
CABP	F4	38°44'30"N 073°03'12"W	179	12	NOV	1976
CABP	F4	38°44'36"N 073°03'06"W	183	18	MAR	1976
CABP	G5	39°48'54"N 072°12'06"W	85	08	MAR	1977
CABP	G5	39°48'54"N 072°12'18"W	90	09	MAR	1976
CABP	G5	39°48'54"N 072°12'24"W	92	27	AUG	1976
CABP	G5	39°49'00"N 072°12'06"W	90	14	AUG	1977
CABP	G6	39°40'36"N 072°00'48"W	167	09	MAR	1976
CABP	I2	39°07'30"N 072°48'54"W	93	22	AUG	1976
CABP	I2	39°07'30"N 072°49'00"W	95	09	AUG	1977
CABP	I2	39°07'30"N 072°49'06"W	93	13	FEB	1977
CABP	K4	38°04'36"N 074°01'42"W	103	16	FEB	1977
CABP	K5	38°01'30"N 073°53'48"W	152	16	FEB	1977

CABP	K5	38°04'36"N 073°53'54"W	140-150	31	AUG	1976
CABP	L3	37°13'36"N 074°46'36"W	66	01	SEP	1976
CABP	L4	37°08'06"N 074°36'54"W	90-91	01	SEP	1976
CABP	L4	37°08'06"N 074°36'54"W	94	13	MAR	1977
CABP	L4	37°08'06"N 074°36'54"W	97	04	AUG	1977
CABP	L4	37°08'06"N 074°37'00"W	94	22	MAR	1976
CABP	L5	37°06'12"N 074°33'24"W	190	16	FEB	1977
CABP	L5	37°06'30"N 074°33'36"W	140	05	AUG	1977
GODCHARLES, M.E.		27°36'08"N 082°46'32"W	3.66	15	APR	1970
GRAY, M.	359	30°48'05"N 080°00'00"W	140.61	12	SEP	1963
HUBRICHT, L.		29°48'42"N 085°18'11"W		31	JUL	1939
K & S	FLK2,3,5,6+	24°32'53"N 081°24'22"W.	31-6.1	08	SEP	1982
LMRS	MS02	31°41'06"N 080°20'48"W	27	05	NOV	1981
MAFLA	2101	26°25'00"N 081°15'09"W	11	--	MAY	1976
MAFLA	2102	26°25'00"N 082°25'00"W	18	--	---	----
MAFLA	2103	26°25'00"N 082°58'00"W	33	--	JUL	1976
MAFLA	2104	26°25'00"N 083°23'01"W	53	--	AUG	1977
MAFLA	2105	26°45'00"N 083°49'58"W	90	--	JUL	1976
MAFLA	2062	6°24'57"N 084°15'00"W	168	--	---	----
MAFLA	2207	27°57'00"N 083°09'00"W	19	--	AUG	1977
MAFLA	2210	27°57'29"N 083°42'29"W	37	--	JUL	1975
MAFLA	2211	27°56'30"N 083°53'00"W	43	--	AUG	1977
MAFLA	2212	27°57'00"N 084°48'00"W	189	--	NOV	1977
MAFLA	2313	28°23'59"N 085°15'03"W	177	29	AUG	1977
MAFLA	2314	28°29'--"N 084°21'--"W	29	--	---	----
MAFLA	2315	28°33'59"N 084°20'09"W	38	--	---	1974
MAFLA	2317	28°56'00"N 084°06'00"W	29	--	NOV	1977
MAFLA	2318	29°05'01"N 083°45'00"W	20	--	JUL	1976
MAFLA	2419	29°47'00"N 084°05'00"W	10	--	SEP	1977
MAFLA	2422	29°30'--"N 084°27'--"W	24	--	---	----
MAFLA	2423	29°37'01"N 084°17'00"W	19	--	AUG	1977
MAFLA	2424	29°13'01"N 085°00'01"W	27	--	---	1975
MAFLA	2425	29°05'--"N 085°15'--"W	36	--	---	----
MAFLA	2426	28°57'59"N 085°23'00"W	82	--	SEP	1977
MAFLA	2427	28°49'59"N 085°37'02"W	175	--	FEB	1975
MAFLA	2528	29°54'59"N 086°04'58"W	37	--	JUL	1976
MAFLA	2529	29°55'59"N 086°06'29"W	38	--	JUL	1976
MAFLA	2530	29°51'--"N 086°06'30"W	41	07	FEB	1976
MAFLA	2531	29°47'59"N 086°09'29"W	45	07	FEB	1976
MAFLA	2532	29°46'--"N 086°12'30"W	52	--	JUL	1976
MAFLA	2533	29°43'00"N 085°15'29"W	67	--	---	----
MAFLA	2534	29°40'--"N 086°17'--"W	73	--	---	----
MAFLA	2638	29°55'29"N 088°33'28"W	24	--	---	----
MAFLA	2639	26°53'30"N 088°12'28"W	32	18	JAN	1976
MAFLA	2640	29°43'29"N 087°54'30"W	35	--	JUL	1976
MAFLA	2641	29°45'29"N 087°46'30"W	37	--	JUL	1976
MAFLA	2642	29°40'30"N 087°37'--"W	36	18	JAN	1976
MAFLA	2643	29°36'31"N 087°27'01"W	69	19	JAN	1976
MAFLA	2644	29°36'12"N 087°23'30"W	75	27	SEP	1975
MAFLA	2645	29°35'00"N 087°20'02"W	106	19	JAN	1976
MAFLA	2747	27°24'12"N 084°07'18"W	74	--	AUG	1977
MAFLA	2748	27°37'12"N 083°53'30"W	50	--	SEP	1977
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	---	----
MAFLA	2856	29°54'01"N 087°24'00"W	30	--	JUL	1976
MAFLA	2957	25°40'--"N 084°15'--"W	180	--	NOV	1977

MAFLA	2959	25°40'--"N 083°05'--"W	60	--	FEB	1978
MAFLA	2960	25°40'--"N 082°20'--"W	27	--	AUG	1977
MARKHAM, J.C.		32°20'--"N 064°40'--"W	90	30	OCT	1976
MMS		31°23'36"N 080°53'12"W	.61	--	---	----
MMS		33°32'18"N 077°25'00"W	1	--	---	----
PIERCE, E.L.		29°09'28"N 083°02'48"W		13	APR	1957
PIERCE, E.L.		29°09'28"N 083°02'48"W	3.05	19	JAN	1957
SABP	1C	33°35'06"N 078°03'58"W	16	16	NOV	1977
SABP	2E	32°39'58"N 078°47'03"W	35	18	AUG	1977
SABP	3C	32°13'00"N 079°52'03"W	20	23	AUG	1977
SABP	4B	31°53'01"N 080°46'00"W	8	25	AUG	1977
SABP	4C	31°45'26"N 080°29'03"W	20	24	FEB	1977
SABP	4C	31°45'27"N 080°29'06"W	18	25	AUG	1977
SABP	4D	31°39'59"N 080°16'05"W	26	24	FEB	1977
SABP	5B	31°11'59"N 081°08'00"W	10.5	21	FEB	1977
SABP	5B	31°11'59"N 081°08'00"W	11	23	NOV	1977
SABP	5C	31°07'59"N 080°49'55"W	15	16	MAY	1977
SABP	5C	31°08'01"N 080°49'57"W	19	23	NOV	1977
SABP	5C	31°08'01"N 080°49'58"W	19	23	NOV	1977
SABP	5C	31°08'02"N 080°49'57"W	19	23	NOV	1977
SABP	5H	30°57'03"N 079°57'58"W	92	25	NOV	1977
SABP	6B	30°22'59"N 081°15'02"W	19	28	FEB	1977
SABP	6B	30°22'59"N 081°15'03"W	12	31	AUG	1977
SABP	6B	30°22'59"N 081°15'03"W	19	28	FEB	1977
SABP	6C	30°22'59"N 080°51'00"W	29	28	FEB	1977
SABP	6G	30°23'06"N 080°09'59"W	149	01	MAR	1977
SABP	7B	29°28'00"N 080°57'08"W	14	04	SEP	1977
SOFLA	03	26°45'52"N 083°21'26"W	50.2	--	---	----
SOFLA	05	26°45'42"N 084°00'08"W	89.8	--	---	----
SOFLA	07	26°16'49"N 082°44'01"W	30.4	--	---	----
SOFLA	09	26°16'50"N 083°23'49"W	55.5	--	---	1974
SOFLA	10	26°16'44"N 083°42'49"W	71.3	--	---	1974
SOFLA	11	26°16'43"N 083°46'49"W	77	--	---	----
SOFLA	12	26°16'43"N 083°47'40"W	89.8	30	APR	1981
SOFLA	13	25°45'56"N 082°09'21"W	19.6	--	---	----
SOFLA	14	25°46'01"N 082°23'49"W	26.1	28	JUL	1981
SOFLA	15	25°45'53"N 082°31'37"W	31.5	--	---	----
SOFLA	16	25°45'42"N 083°11'04"W	53.7	28	JUL	1981
SOFLA	18	25°45'22"N 083°42'13"W	86.1	--	---	1974
SOFLA	19	25°17'22"N 082°09'00"W	22.5	--	---	1974
SOFLA	20	25°17'20"N 082°09'44"W	22.7	--	---	1974
SOFLA	21	25°17'16"N 082°52'10"W	44.2	--	---	----
SOFLA	22	25°17'11"N 083°02'04"W	52.2	01	AUG	1981
SOFLA	23	25°16'53"N 083°37'47"W	70	--	---	----
SOFLA	24	25°16'54"N 083°43'11"W	88.2	--	---	----
SOFLA	25	24°47'57"N 082°13'16"W	24	--	---	----
SOFLA	26	24°47'49"N 082°52'04"W	38	--	---	----
SOFLA	28	24°47'07"N 083°13'05"W	58.6	04	AUG	1981
SOFLA	29	24°27'31"N 083°41'11"W	62.5	--	---	1974
SOFLA	30	24°47'25"N 083°51'09"W	76.1	--	---	1974
SOFLA	33	26°16'32"N 084°05'58"W	145.5	--	---	----
SOFLA	34	25°45'19"N 083°57'38"W	135.5	27	JUL	1981
SOFLA	35	25°44'50"N 084°21'02"W	159	--	---	----
SOFLA	36	25°16'50"N 083°57'21"W	127	--	---	----
SOFLA	37	25°16'38"N 084°09'23"W	148	02	AUG	1981

SOFLA	38	25°16'30"N 084°14'46"W	159	--	---	1974
SOFLA	39	24°47'10"N 083°55'22"W		--	---	----
SOFLA	40	26°46'45"N 082°30'25"W	18	--	---	----
SOFLA	42	26°17'01"N 082°25'25"W	17	--	---	1974
SOFLA	43	26°17'24"N 082°18'53"W	16	--	---	1974
SOFLA	45	26°03'11"N 082°08'27"W	17	--	---	----
SOFLA	46	26°01'01"N 082°07'53"W	18	--	---	1974
SOFLA	48	25°46'09"N 082°01'06"W	16	--	---	1974
SOFLA	50	25°17'48"N 081°39'48"W	14	--	---	1974
SOFLA	50	25°20'30"N 081°51'30"W	16	--	---	1974
VOGEL, J.		27°41'18"N 082°34'21"W		17	MAY	1967
VOGEL, J.		27°53'09"N 082°33'31"W		01	OCT	1966
VOGEL, J.		27°53'09"N 082°33'31"W		09	NOV	1966
VOGEL, J.		27°53'09"N 082°33'31"W		10	JUL	1966
WASS, M.	0	29°56'51"N 084°20'29"W		01	DEC	1955

AMAKUSANTHURA   SIGNATA

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
AUSTIN, H.	VII-9	17°58'--"N 067°04'--"W	1.53	23	JUL	1966
K & S	K-DOM-19,20,22	15°14'--"N 061°19'--"W	.5-5	18	NOV	1992
K & S	K-DOM-4,25,26	15°35'--"N 061°16'--"W		22	MAR	1989
KENSLEY, B.	K-10	16°48'--"N 088°05'--"W	1.2	01	FEB	1978
LMRS	IS01	32°29'18"N 079°42'42"W	18	31	JUL	1981
LMRS	IS01	32°29'36"N 079°42'30"W	18	26	---	1981
LMRS	IS02	31°23'30"N 080°53'12"W	18	28	JUL	1981
LMRS	IS02	31°23'36"N 080°53'12"W	17	13	MAY	1981
LMRS	IS02	31°23'36"N 080°53'12"W	18	28	JUL	1981
LMRS	IS02	31°23'36"N 080°53'12"W	19	26	FEB	1981
LMRS	MS06	32°49'24"N 078°39'48"W	34	--	---	----
MAFLA	2101	26°25'00"N 081°15'09"W	11	--	AUG	1977
MAFLA	2316	28°42'00"N 084°20'01"W	35	--	FEB	1978
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	AUG	1977
M & G	VIII-15	17°56'--"N 067°06'--"W		06	AUG	1966
SOFLA	11	26°16'43"N 083°46'49"W	77	--	---	----
SOFLA	12	26°16'43"N 083°47'40"W	89.8	--	---	----
SOFLA	22	25°17'11"N 083°02'04"W	52.2	--	---	----
SOFLA	23	25°16'53"N 083°37'47"W	70	--	---	----
SOFLA	25	24°47'57"N 082°13'16"W	24	--	---	----
SOFLA	26	24°47'49"N 082°52'04"W	38	--	---	----
SOFLA	30	24°47'25"N 083°51'09"W	76.1	--	---	----
SOFLA	33	26°16'32"N 084°05'58"W	145.5	--	---	----
SOFLA	34	25°45'19"N 083°57'38"W	135.5	--	---	----
SOFLA	35	25°44'50"N 084°21'02"W	159	--	---	----
SOFLA	36	25°16'50"N 083°57'21"W	127	--	---	----
SOFLA	37	25°16'38"N 084°09'23"W	148	--	---	----

CYATHURA   BURBANCKI

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
		40°36'44"N 073°41'34"W	1.22	24	JUL	1967
FRANKENBERG, D.		31°19'15"N 081°07'45"W	17	26	APR	1963
SABP	1F	33°00'56"N 077°20'15"W	225	17	AUG	1977

SABP	2A	32°56'59"N 079°16'54"W	15	19	AUG	1977
SABP	2F	32°36'02"N 078°38'58"W	44	14	FEB	1977
SABP	3B	32°23'00"N 080°09'00"W	13.7	17	FEB	1977
SABP	3B	32°23'26"N 080°08'56"W	11	23	AUG	1977
SABP	3B	32°23'27"N 080°08'56"W	11	23	AUG	1977
SOFLA	01	26°45'46"N 082°43'07"W	24	--	---	----

HYSSURA   BACESCUI

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
EASTWARD R/V	738	34°17'30"N 075°49'--"W	445	13	MAR	1965
MAFLA	13G	29°45'29"N 087°46'30"W	37	--	JUN	1975
MAFLA	2313	28°23'59"N 085°15'03"W	177	--	---	----
SABP	5H	30°57'05"N 079°58'04"W	79	17	MAY	1977
SABP	5I	30°54'04"N 079°43'38"W	422	25	NOV	1977
SABP	7E	29°36'02"N 080°10'51"W	225	27	NOV	1977

KUPELLONURA   FORMOSA

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
GRAY, M.	298	31°26'32"N 079°42'13"W	76.86-88.76	06	AUG	1963
HIGGINS, R.		27°26'47"N 080°15'33"W	15	--	---	----
LMRS	IS02	31°23'36"N 080°53'12"W	17	13	MAY	1981
MAFLA	2316	28°42'00"N 084°20'01"W	35	--	---	1976
MAFLA	2420	29°42'--"N 084°11'--"W	14	--	---	1975
MAFLA	2528	29°54'59"N 086°04'58"W	37	--	NOV	1977
MAFLA	2640	29°43'29"N 087°54'30"W	35	--	FEB	1978
MAFLA	2643	29°36'31"N 087°27'01"W	69	--	---	----
SABP	2B	32°54'00"N 079°12'00"W	16	12	FEB	1977
SABP	IS02	31°23'36"N 080°53'12"W	17	--	---	----
SABP	OS02	34°51'24"N 075°31'12"W	57	--	---	----
SOFLA	12	26°16'43"N 083°47'40"W	89.8	--	---	----
SOFLA	20	25°17'20"N 082°09'44"W	22.7	--	---	----
SOFLA	28	24°47'07"N 083°13'05"W	58.6	04	AUG	1981
SOFLA	29	24°27'31"N 083°41'11"W	62.5	--	---	----
SOFLA	30	24°47'25"N 083°51'09"W	76.1	--	---	----
SOFLA	32	26°16'40"N 084°04'05"W	137	--	---	--
SOFLA	33	26°16'32"N 084°05'58"W	145.5	--	---	----
SOFLA	34	25°45'19"N 083°57'38"W	135.5	--	---	----
SOFLA	35	25°44'50"N 084°21'02"W	159	--	---	----

NEOHYSSURA   IRPEX

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
GRAY, M.	366	30°45'00"N 080°02'56"W	86.93	12	SEP	1963
MAFLA	2103	26°25'00"N 082°58'00"W	33	--	----	----
MAFLA	2104	26°25'00"N 083°23'01"W	53	--	AUG	1977
MAFLA	2105	26°45'00"N 083°49'58"W	90	--	MAY	1975
MAFLA	2106	26°24'57"N 084°15'00"W	168	--	---	1977
MAFLA	2211	27°56'30"N 083°53'00"W	43	--	AUG	1978
MAFLA	2313	28°23'59"N 085°15'03"W	177	--	AUG	1977
MAFLA	2315	28°33'59"N 084°20'09"W	38	--	---	1974

MAFLA	2316	28°42'00"N 084°20'01"W	35	--	---	1976
MAFLA	2317	28°56'00"N 084°06'00"W	29	--	---	----
MAFLA	2423	29°37'01"N 084°17'00"W	19	--	SEP	1977
MAFLA	2426	28°57'59"N 085°23'00"W	82	--	NOV	1977
MAFLA	2427	28°49'59"N 085°37'02"W	175	--	---	----
MAFLA	2528	29°54'59"N 086°04'58"W	37	--	SEP	1977
MAFLA	2529	29°55'59"N 086°06'29"W	38	--	SEP	1977
MAFLA	2530	29°51'--"N 086°06'30"W	41	--	---	----
MAFLA	2531	29°47'59"N 086°09'29"W	45	--	FEB	1978
MAFLA	2533	29°43'00"N 085°15'29"W	67	--	AUG	1977
MAFLA	2534	29°40'--"N 086°17'--"W	73	--	---	----
MAFLA	2535	29°37'00"N 086°20'00"W	117	--	---	----
MAFLA	2640	29°43'29"N 087°54'30"W	35	--	AUG	1977
MAFLA	2642	29°40'30"N 087°37'--"W	36	--	---	----
MAFLA	2644	29°36'12"N 087°23'30"W	75	--	---	----
MAFLA	2645	29°35'00"N 087°20'02"W	106	--	SEP	1977
MAFLA	2747	27°24'12"N 084°07'18"W	74	--	---	----
MAFLA	2748	27°37'12"N 083°53'30"W	50	--	AUG	1977
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	---	----
MAFLA	2957	25°40'--"N 084°15'--"W	180	--	AUG	1977
MAFLA	2958	25°40'--"N 083°50'--"W	120	--	AUG	1977
SABP	2D	32°44'55"N 078°55'56"W	32	18	AUG	1977
SABP	4C	31°45'--"N 080°28'--"W	16	--	---	1977
SABP	4C	31°45'26"N 080°29'03"W	20	24	FEB	1977
SABP	4C	31°45'27"N 080°29'06"W	18	25	AUG	1977
SABP	5B	31°11'59"N 081°08'00"W	10.5	21	FEB	1977
SABP	5B	31°12'--"N 081°08'--"W	11	--	---	1977
SABP	5B	31°12'00"N 081°07'59"W	10.5	21	FEB	1977
SABP	5C	31°08'00"N 080°49'57"W	19	25	FEB	1977
SABP	5C	31°08'02"N 080°49'57"W	19	23	NOV	1977
SABP	5F	31°01'01"N 080°16'59"W	36	17	MAY	1977
SABP	5F	31°01'02"N 080°16'57"W	36	16	MAY	1977
SABP	5H	30°57'05"N 079°58'04"W	79	17	MAY	1977
SABP	6H	30°23'03"N 079°56'59"W	460	02	MAR	1977
SABP	OS04	34°51'24"N 075°31'12"W	57	--	---	----
SABP	OS05	33°49'48"N 076°34'36"W	61	--	---	----
SOFLA	04	26°45'49"N 083°32'07"W	55.2	29	OCT	1980
SOFLA	16	25°45'42"N 083°11'04"W	53.7	09	NOV	1980
SOFLA	18	25°45'22"N 083°42'13"W	86.1	15	NOV	1980
SOFLA	19	25°17'22"N 082°09'00"W	22.5	18	NOV	1980
SOFLA	20	25°17'20"N 082°09'44"W	22.7	18	NOV	1980
SOFLA	22	25°17'11"N 083°02'04"W	52.2	17	NOV	1980
SOFLA	24	25°16'54"N 083°43'11"W	88.2	16	NOV	1980
SOFLA	28	24°47'07"N 083°13'05"W	58.6	20	NOV	1980
SOFLA	33	26°16'32"N 084°05'58"W	145.5	05	FEB	1982
SOFLA	34	25°45'19"N 083°57'38"W	135.5	27	JUL	1981
SOFLA	35	25°44'50"N 084°21'02"W	159	07	FEB	1982
SOFLA	37	25°16'38"N 084°09'23"W	148	09	FEB	1982
SOFLA	39	24°47'10"N 083°55'22"W	151.5	10	FEB	1982

PTILANTHURA   COLPOS

Program/Donor	Station	Latitude/Longitude	Depth (meters)	Date Collected		
CGPS	03P-W2000-05	28°40'02"N 090°14'43"W	32	29	MAY	1978

CGPS	03P-W2000-07	28°40'02"N 090°14'43"W	32	29	MAY	1978
CGPS	14S-N2000-07·	28°41'51"N 091°37'21"W	27	20	SEP	1978
CGPS	14S-N500-08	28°41'51"N 091°37'21"W	27	20	SEP	1978
CGPS	18S-N2000-07	28°48'50"N 091°44'20"W	24	20	SEP	1978
CGPS	18S-N2000-08	28°48'50"N 091°44'20"W	24	20	SEP	1978
MAFLA	15I	29°45'29"N 087°46'30"W	37	--	---	1974
MAFLA	17F	29°36'31"N 087°27'01"W	69	--	---	1975
MAFLA	2102	26°25'00"N 082°25'00"W	18 ,	--	---	----
MAFLA	2210	27°57'29"N 083°42'49"W	37	--	JUL	1975
MAFLA	2317	28°56'00"N 084°06'00"W	20	--	---	1975
MAFLA	2420	29°42'--"N 084°11'--"W	14	--	---	1976
MAFLA	2426	28°57'59"N 085°23'00"W	82	--	JUL	1978
MAFLA	2639	26°53'30"N 088°12'28"W	32	18	JAN	1976
MAFLA	2641	29°45'29"N 087°46'30"W	37	--	JUL	1976
MAFLA	2642	29°40'30"N 087°37'--"W	36	27	SEP	1975
MAFLA	2643	29°36'31"N 087°27'01"W	69	--	---	----
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	---	1976
MAFLA	2854	29°24'00"N 085°42'02"W	42	--	JUL	1976
MAFLA	2856	29°54'01"N 087°24'00"W	30	--	JUL	1976
MAFLA	8G	29°53'30"N 088°12'28"W	32	--	---	1974
SOFLA	24	25°16'54"N 083°43'11"W	88.2	14	AUG	1981

PTILANTHURA   TENUIS

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
BATTELLE	FF 10 REP. 3	42°24'52"N 070°52'44"W	29	16	AUG	1993
BATTELLE	NF 14 REP. 2	42°23'15"N 070°49'25"W	34	16	AUG	1993
BATTELLE	NF 4 REP. 1	42°24'58"N 070°48'23"W	38	15	AUG	1993
CABP	A1	39°14'18"N 072°46'48"W	90	21	AUG	1976
CABP	A1	39°14'30"N 072°47'30"W	91	15	NOV	1976
CABP	A1	39°14'42"N 072°42'24"W	89	07	AUG	1977
CABP	B2	39°23'18"N 073°00'36"W	61	04	MAR	1976
CABP	B3	39°19'42"N 073°00'12"W	72	11	FEB	1977
CABP	B3	39°19'42"N 073°00'18"W	72	04	MAR	1976
CABP	B3	39°19'42"N 073°00'24"W	72	04	NOV	1975
CABP	BD2	39°28'24"N 072°58'42"W	64	15	NOV	1976
CABP	BD6	39°20'06"N 072°59'00"W	74	15	NOV	1976
CABP	BD7	39°20'54"N 073°08'06"W	64	15	NOV	1976
CABP	BD8	39°20'18"N 073°10'06"W	64	15	NOV	1976
CABP	BF2	39°28'54"N 073°06'48"W	54	15	NOV	1976
CABP	BF3	39°26'06"N 073°08'24"W	58	15	NOV	1976
CABP	BF6	39°21'54"N 073°09'48"W	62	15	NOV	1976
CABP	BM1	39°25'00"N 073°13'48"W	56	15	NOV	1976
CABP	BM2	39°23'42"N 073°13'12"W	58	15	NOV	1976
CABP	BM4	39°22'24"N 073°12'54"W	56	15	NOV	1976
CABP	BM5	39°20'06"N 073°12'42"W	63	15	NOV	1976
CABP	BM6	39°20'00"N 073°10'42"W	63	15	NOV	1976
CABP	BP4	39°32'54"N 073°08'30"W	46	15	NOV	1976
CABP	BR1	39°21'24"N 073°11'00"W	62	15	NOV	1976
CABP	BR3	39°22'18"N 073°03'30"W	66	14	NOV	1976
CABP	BR4	39°19'48"N 072°58'30"W	65	15	NOV	1976
CABP	BR6	39°30'36"N 072°59'24"W	66	15	NOV	1976
CABP	BR8	39°34'30"N 072°57'24"W	65	15	NOV	1976
CABP	BR9	39°32'18"N 072°57'30"W	62	15	NOV	1976

CABP	BS0	39°27'54"N 072°58'30"W	66	15	NOV	1976
CABP	BS1	39°32'00"N 073°01'30"W	71	15	NOV	1976
CABP	BS2	39°30'24"N 073°00'42"W	69	15	NOV	1976
CABP	BS3	39°28'42"N 073°05'06"W	66	15	NOV	1976
CABP	BS4	39°24'54"N 073°07'30"W	64	15	NOV	1976
CABP	BS5	39°25'06"N 073°06'30"W	66	15	NOV	1976
CABP	BS6	39°24'12"N 073°06'12"W	66	15	NOV	1976
CABP	BS8	39°20'24"N 073°00'00"W	75	15	NOV	1976
CABP	BS9	39°20'48"N 072°58'18"W	74	15	NOV	1976
CABP	D1	39°04'36"N 073°53'30"W	39-40	21	FEB	1976
CABP	D4	39°02'54"N 073°47'06"W	48	17	AUG	1976
CABP	D4	39°02'54"N 073°47'06"W	51	17	JUN	1976
CABP	D4	39°02'54"N 073°47'12"W	49	21	FEB	1976
CABP	D4	39°03'00"N 073°47'12"W	49	08	FEB	1977
CABP	D4	39°03'00"N 073°47'12"W	49	12	AUG	1977
CABP	E1	38°47'06"N 073°27'24"W	66	17	JUN	1976
CABP	E1	38°47'18"N 073°23'48"W	68	17	AUG	1976
CABP	E1	38°49'00"N 073°25'18"W	60	09	FEB	1977
CABP	E1	38°49'06"N 073°25'18"W	63	11	AUG	1977
CABP	E2	38°44'06"N 073°25'00"W	73	18	JUN	1976
CABP	E2	38°44'12"N 073°25'36"W	70	18	AUG	1976
CABP	E2	38°44'18"N 073°25'30"W	74	09	MAR	1977
CABP	E2	38°45'12"N 073°25'12"W	76	11	AUG	1977
CABP	E3	38°41'18"N 073°32'00"W	63	18	AUG	1976
CABP	E3	38°41'24"N 073°32'24"W	56	18	JUN	1976
CABP	E4	38°42'36"N 073°24'18"W	75	18	AUG	1976
CABP	E4	38°42'42"N 073°24'54"W	80	11	AUG	1977
CABP	E4	38°42'48"N 073°24'18"W	80	17	JUN	1976
CABP	ED1	38°41'12"N 073°30'48"W	69	09	NOV	1976
CABP	ED2	38°46'00"N 073°26'54"W	70	10	NOV	1976
CABP	ED3	38°46'00"N 073°30'06"W	70	10	NOV	1976
CABP	ED4	38°48'18"N 073°29'00"W	70	10	NOV	1976
CABP	ED5	38°50'12"N 073°25'12"W	69	10	NOV	1976
CABP	EF1	38°48'30"N 073°36'36"W	57	10	NOV	1976
CABP	EF3	38°45'48"N 073°36'00"W	62	10	NOV	1976
CABP	EF5	38°44'54"N 073°34'00"W	66	10	NOV	1976
CABP	EL4	38°41'06"N 073°17'06"W	89	11	NOV	1976
CABP	EL5	38°40'12"N 073°17'54"W	87	11	NOV	1976
CABP	ES8	38°44'48"N 073°17'24"W	79	11	NOV	1976
CABP	F1	38°43'30"N 073°13'54"W	84	20	AUG	1976
CABP	F1	38°44'06"N 073°14'42"W	85	12	NOV	1976
CABP	F1	38°44'18"N 073°14'36"W	86	19	JUN	1976
CABP	F1	38°45'24"N 073°16'18"W	79	09	FEB	1977
CABP	F1	38°45'24"N 073°16'30"W	82	10	AUG	1977
CABP	F2	38°43'42"N 073°08'30"W	113	20	AUG	1976
CABP	F2	38°44'12"N 073°09'06"W	110	18	MAR	1976
CABP	F2	38°44'12"N 073°09'06"W	116	11	AUG	1977
CABP	F2	38°44'18"N 073°08'54"W	103	10	FEB	1977
CABP	F2	38°44'18"N 073°09'18"W	111	12	NOV	1976
CABP	F3	38°43'36"N 073°04'30"W	151	12	NOV	1976
CABP	F3	38°43'48"N 073°04'06"W	155	10	FEB	1977
CABP	F3	38°43'54"N 073°04'06"W	162	10	AUG	1977
CABP	G3	39°43'00"N 072°54'06"W	71	08	MAR	1977
CABP	G3	39°43'06"N 072°54'12"W	73	27	AUG	1976
CABP	G3	39°43'06"N 072°54'12"W	74	14	AUG	1977

CABP	G3	39°43'42"N 072°54'42"W	73-74	08	MAR	1976
CABP	I1	39°06'36"N 072°59'00"W	77	23	AUG	1976
CABP	K2	38°12'36"N 074°26'30"W	42	23	AUG	1976
CABP	K4	38°04'30"N 074°01'36"W	103	16	AUG	1977
CABP	K4	38°04'30"N 074°01'42"W	105	12	MAR	1976
CABP	K4	38°04'36"N 074°01'42"W	103	16	FEB	1977
CABP	K5	38°01'30"N 073°53'48"W	152	16	FEB	1977
CABP	K5	38°04'36"N 073°53'54"W	140-150	31	AUG	1976
CABP	K6	38°00'36"N 073°51'54"W	339-370	31	AUG	1976
CABP	L2	37°20'12"N 074°58'36"W	41	22	MAR	1976
CABP	L2	37°20'12"N 074°58'36"W	43	04	AUG	1977
CABP	L2	37°20'12"N 074°58'36"W	43	17	FEB	1977
CABP	L2	37°20'12"N 074°58'36"W	48	01	SEP	1976
CABP	L3	37°13'36"N 074°46'36"W	58	22	MAR	1976
CABP	L4	37°08'06"N 074°36'54"W	90-91	01	SEP	1976
CABP	L4	37°08'06"N 074°36'54"W	94	13	MAR	1977
CABP	L4	37°08'06"N 074°36'54"W	97	04	AUG	1977
CABP	L4	37°08'06"N 074°37'00"W	94	22	MAR	1976
GRAY, M.B.	229	31°07'59"N 080°27'17"W	28.37	08	JUL	1963
MAFLA	2207	27°57'00"N 083°09'00"W	19	--	---	----
MAFLA	2210	27°57'29"N 083°42'29"W	37	--	---	----
MAFLA	2424	29°13'01"N 085°00'01"W	27	--	---	----
MAFLA	2426	28°57'59"N 085°23'00"W	82	--	---	----
MAFLA	2640	29°43'29"N 087°54'30"W	35	--	---	----
MAFLA	2856	29°54'01"N 087°24'00"W	30	--	---	----
NEEB	01	41°07'12"N 070°32'58"W	38	11	FEB	1977
NEEB	01	41°07'37"N 070°33'04"W	38	11	FEB	1977
NEEB	02	40°43'18"N 069°52'05"W	45	15	FEB	1977
NEEB	02	40°43'26"N 069°52'26"W	46	15	FEB	1977
NEEB	03	40°39'27"N 069°27'25"W	57	15	FEB	1977
NEEB	03	40°39'38"N 069°27'23"W	56	15	FEB	1977
NEEB	03	40°39'39"N 069°27'21"W	58	15	FEB	1977
NEEB	06	40°25'45"N 070°03'09"W	73	12	FEB	1977
NEEB	07	40°13'13"N 069°47'14"W	87	22	MAY	1977
NEEB	07	40°13'26"N 069°47'23"W	86	13	FEB	1977
NEEB	08	40°21'22"N 068°29'35"W	106	06	MAY	1977
NEEB	13	40°41'21"N 067°35'31"W	84	06	MAR	1977
NEEB	13	40°41'47"N 067°35'04"W	84	06	MAR	1977
NEEB	13	40°41'47"N 067°35'07"W	84	06	MAR	1977
NEEB	14	40°43'18"N 067°36'18"W	79	08	MAY	1977
NEEB	14	40°43'23"N 067°36'10"W	80	18	FEB	1977
NEEB	14	40°43'28"N 067°36'26"W	79	08	MAY	1977
NEEB	15	40°43'34"N 067°33'55"W	83	08	MAY	1977
NEEB	16	40°42'26"N 067°34'22"W	84	08	MAY	1977
NEEB	16	40°42'28"N 067°34'16"W	84	08	MAY	1977
NEEB	16	40°42'30"N 067°34'26"W	86	19	FEB	1977
NEEB	16	40°42'30"N 067°34'26"W	87	19	FEB	1977
NEEB	16	40°42'49"N 067°34'15"W	83	08	MAY	1977
NEEB	16	40°42'49"N 067°34'29"W	83	08	MAY	1977
NEEB	19	40°34'24"N 067°45'00"W	84	18	FEB	1977
NEEB	19	40°34'24"N 067°45'00"W	87	18	FEB	1977
NEEB	19	40°34'24"N 067°45'00"W	90	17	FEB	1977
NEEB	19	40°34'32"N 067°45'10"W	95	07	MAY	1977
NEEB	20	40°35'58"N 067°44'39"W	77	18	FEB	1977
NEEB	20	40°36'09"N 067°45'07"W	84	07	MAY	1977

NEEB	20	40°36'11"N 067°45'04"W	84	07	MAY	1977
NEEB	21	40°43'59"N 067°18'36"W	96	09	MAY	1977
NEEB	21	40°43'59"N 067°18'38"W	98	09	MAY	1977
NEEB	21	40°44'02"N 067°18'31"W	96	09	MAY	1977
NEEB	21	40°44'12"N 067°18'27"W	90	20	FEB	1977
NEEB	22	40°23'44"N 067°28'41"W	253	07	MAY	1977
NEEB	23	40°29'38"N 067°42'39"W	178	16	FEB	1977
NEEB	28	40°54'34"N 066°46'56"W	93	20	FEB	1977
NEEB	28	40°54'42"N 066°46'41"W	89	21	AUG	1977
NEEB	29	40°58'22"N 066°54'58"W	68	20	FEB	1977
NEEB	29	40°58'24"N 066°55'04"W	73	10	MAY	1977
NEEB	33	41°32'26"N 066°02'51"W	104	04	MAR	1977
SABP	1A	33°49'38"N 078°23'08"W	10	15	AUG	1977
SABP	1E	33°12'02"N 077°35'11"W	43	10	MAY	1977
SABP	1E	33°12'02"N 077°35'12"W	43	10	MAY	1977
SABP	1E	33°12'03"N 077°35'11"W	43	10	MAY	1977
SABP	1E	33°12'05"N 077°35'13"W	44	19	NOV	1977
SABP	2D	32°44'55"N 078°55'56"W	32	18	AUG	1977
SABP	2E	32°39'58"N 078°47'03"W	35	18	AUG	1977
SABP	2F	32°36'02"N 078°38'58"W	44	14	FEB	1977
SABP	3D	32°05'00"N 079°37'58"W	39	17	FEB	1977
SABP	4B	31°53'01"N 080°46'00"W	8	25	AUG	1977
SABP	4D	31°39'59"N 080°16'01"W	21	27	AUG	1977
SABP	4F	31°27'00"N 079°46'03"W	65	23	FEB	1977
SABP	5D	31°05'--"N 080°35'--"W	21	--	---	----
SABP	5E	31°02'58"N 080°25'59"W	33	26	FEB	1977
SABP	5F	31°01'00"N 080°17'01"W	36	17	MAY	1977
SABP	5C	31°08'00"N 080°49'50"W	13	31	AUG	1977
USFC		43°45'--"N 070°00'--"W		04	AUG	1973
USGS	WH2	42°22'52"N 070°48'53"W	32	--	MAY	1992

XENANTHURA   BREVITELSON

Program/Donor	Station	Latitude/Longitude	Depth (meters)		Date Collected	
CGPS	03P	28°40'02"N 090°14'43"W	29	09	JAN	1979
CGPS	03P	28°40'02"N 090°14'43"W	32	28	MAY	1978
CRYSTAL RIVER 316 STUDIES	13	28°55'23"N 082°42'50"W	.39-.96	13	JUN	1983
DUKE UNIV. LAB	473	34°41'37"N 076°40'00"W		--	---	----
HEARD, R.		24°20'--"N 077°51'--"W	.5-1	14	APR	1988
MAFLA	11	29°43'29"N 087°54'30"W	35	--	---	1974
MAFLA	13J	29°38'30"N 087°45'--"W	35	--	---	1974
MAFLA	14	29°36'00"N 087°48'00"W	37	--	---	----
MAFLA	15	29°45'29"N 087°46'30"W	37	--	---	1974
MAFLA	16	29°40'30"N 087°37'00"W	36	--	---	1974
MAFLA	17	29°36'31"N 087°27'01"W	69	--	JUN	1975
MAFLA	2101	26°25'00"N 081°15'09"W	11	--	MAY	1975
MAFLA	2102	26°25'00"N 082°25'00"W	18	--	MAY	1975
MAFLA	2103	26°25'00"N 082°58'00"W	33	--	JUL	1976
MAFLA	2104	26°25'00"N 083°23'01"W	53	--	MAY	1975
MAFLA	2105	26°45'00"N 083°49'58"W	90	--	MAY	1975
MAFLA	2106	26°24'57"N 084°15'00"W	168	--	MAY	1975
MAFLA	2207	27°57'00"N 083°09'00"W	19	--	SEP	1975
MAFLA	2208	27°56'00"N 083°27'30"W	30	--	---	----
MAFLA	2209	27°52'00"N 083°33'59"W	34	--	FEB	1978

MAFLA	2210	27°57'29"N 083°42'29"W	37	--	JUL	1975
MAFLA	2211	27°56'30"N 083°53'00"W	43	--	FEB	1976
MAFLA	2212	27°57'00"N 084°48'00"W	189	--	---	1976
MAFLA	2313	28°23'59"N 085°15'03"W	177	--	---	----
MAFLA	2314	28°29'--"N 084°21'--"W	29	--	---	1976
MAFLA	2315	28°33'59"N 084°20'09"W	38	--	---	1975
MAFLA	2316	28°42'00"N 084°20'01"W	35	--	FEB	1978
MAFLA	2317	28°56'00"N 084°06'00"W	29	--	---	1975
MAFLA	2318	29°05'01"N 083°45'00"W	20	--	---	1975
MAFLA	2319	29°47'00"N 084°05'00"W	10	--	---	----
MAFLA	2421	29°37'01"N 084°17'00"W	19	--	---	1976
MAFLA	2422	29°30'--"N 084°27'--"W	24	--	---	1976
MAFLA	2423	29°37'01"N 084°17'00"W	19	--	---	1976
MAFLA	2425	29°05'--"N 085°15'--"W	36	--	---	1976
MAFLA	2426	28°57'59"N 085°23'00"W	82	--	---	1975
MAFLA	2528	29°54'59"N 086°04'58"W	37	--	NOV	1977
MAFLA	2530	29°51'--"N 086°06'30"W	41	--	---	----
MAFLA	2531	29°47'59"N 086°09'29"W	45	--	NOV	1977
MAFLA	2640	29°43'29"N 087°54'30"W	35	--	NOV	1977
MAFLA	2641	29°45'29"N 087°46'30"W	37	18	JAN	1976
MAFLA	2642	29°40'30"N 087°37'--"W	36	--	---	----
MAFLA	2643	29°36'31"N 087°27'01"W	69	27	JUL	1975
MAFLA	2644	29°36'12"N 087°23'30"W	75	--	---	----
MAFLA	2746	27°03'30"N 084°13'42"W	121	--	NOV	1976
MAFLA	2747	27°24'12"N 084°07'18"W	74	--	JUL	1976
MAFLA	2748	27°37'12"N 083°53'30"W	50	--	JUL	1976
MAFLA	2851	27°03'26"N 083°01'08"W	36	--	---	1976
MAFLA	2852	28°30'00"N 083°29'58"W	22	--	---	1976
MAFLA	2854	29°24'00"N 085°42'02"W	42	--	JUL	1976
MAFLA	2957	25°40'--"N 084°15'--"W	180	--	NOV	1977
MAFLA	2958	25°40'--"N 083°50'--"W	120	--	NOV	1977
MAFLA	2959	25°40'--"N 083°05'--"W	60	--	AUG	1977
MAFLA	2960	25°40'--"N 082°20'--"W	27	--	FEB	1978
MAFLA	30	29°46'--"N 086°12'30"W	52	--	---	----
MAFLA	46	28°42'00"N 084°20'01"W	35	--	---	1974
MAFLA	55	27°56'30"N 083°53'00"W	43	--	---	----
MAFLA	9	29°53'30"N 088°12'28"W	32	--	---	1974
SOFLA	01	26°45'46"N 082°43'07"W	24	28	OCT	1980
SOFLA	04	26°45'49"N 083°32'07"W	55.2	29	OCT	1980
SOFLA	05	26°45'42"N 084°00'08"W	89.8	02	NOV	1980
SOFLA	06	26°16'47"N 082°38'21"W	26.2	03	MAY	1981
SOFLA	08	26°16'43"N 083°12'49"W	48.4	03	MAY	1981
SOFLA	12	26°16'43"N 083°47'40"W	89.8	30	APR	1981
SOFLA	13	25°45'56"N 082°09'21"W	19.6	28	APR	1981
SOFLA	14	25°46'01"N 082°23'49"W	26.1	28	APR	1981
SOFLA	15	25°45'53"N 082°31'37"W	31.5	28	APR	1981
SOFLA	16	25°45'42"N 083°11'04"W	53.7	29	APR	1981
SOFLA	17	25°45'35"N 083°20'14"W	58.5	29	APR	1981
SOFLA	18	25°45'22"N 083°42'13"W	86.1	29	APR	1981
SOFLA	19	25°17'22"N 082°09'00"W	22.5	27	APR	1981
SOFLA	20	25°17'20"N 082°09'44"W	22.7	27	APR	1981
SOFLA	22	25°17'11"N 083°02'04"W	52.2	26	APR	1981
SOFLA	23	25°16'53"N 083°37'47"W	70	26	APR	1981
SOFLA	24	25°16'54"N 083°43'11"W	88.2	25	APR	1981
SOFLA	25	24°47'57"N 082°13'16"W	24	23	APR	1981

SOFLA	26	24°47'49"N 082°52'04"W	38	23	APR	1981
SOFLA	28	24°47'07"N 083°13'05"W	58.6	24	APR	1981
SOFLA	30	24°47'25"N 083°51'09"W	76.1	25	APR	1981
SOFLA	34	25°45'19"N 083°57'38"W	135.5	27	JUL	1981
SOFLA	37	25°16'38"N 084°09'23"W	148	02	AUG	1981
SOFLA	38	25°16'30"N 084°14'46"W	159	02	AUG	1981
SOFLA	52	25°17'48"N 081°39'48"W	14	09	DEC	1982
WILLIAMS, M.W.	M - 12	30°22'09"N 088°49'54"W		12	DEC	1943

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Stomatopod Crustaceans from the Carolinas and Georgia, Southeastern United States

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STOMATOPOD CRUSTACEANS FROM THE CAROLINAS AND GEORGIA, SOUTHEASTERN UNITED STATES

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ABSTRACT Literature and specimen records are updated for stomatopod crustaceans known from the coasts of the Carolinas and Georgia. *Gibbesia*, new genus, is recognized for *Squilla neglecta*, and a new species, *Neogonodactylus wennerae*, is named for an offshore species of *Neogonodactylus* previously identified with the Caribbean shore species *N. bredini*. Fifteen species of stomatopods representing 12 genera are now known from the area: *Bigelowina biminiensis* (Bigelow), *Cloridopsis dubia* (Milne Edwards), *Coronis scolopendra* Latreille, *Gibbesia neglecta* (Gibbes), *Heterosquilloides armata* (Smith), *Meiosquilla quadridens* (Bigelow), *Lysiosquilla scabricauda* (Lamarck), *Lysiosquillina glabriuscula* (Lamarck), *Nannosquilla carolinensis* Manning, *N. whitingi* Camp & Manning, *Neogonodactylus torus* (Manning), *Neogonodactylus wennerae*, new species, *Platysquilloides enodis* (Manning), *Squilla deceptrix* Manning, and *S. empusa* Say. A key is provided to species known from the Carolinas and Georgia.

INTRODUCTION

Manning (1969) tentatively identified a single specimen of *Nannosquilla* taken at a depth of 15 meters off Sapelo Island, Georgia, with *N. grayi* (Chace 1958), a species otherwise known only from intertidal or shallow sublittoral habitats in Massachusetts. Camp & Manning (1982:2) suggested that the specimen from Georgia might be referable to one of two sublittoral species from the east coast of Florida described by them, *N. baliops* or *N. whitingi*, but at that time the specimen from Georgia was not available for study. Recently, we have been able to examine the specimen of *Nannosquilla* and all of the other stomatopod material in the collection of the University of Georgia.

The results of examining that collection are reported here, together with observations on stomatopods from localities in Georgia made by one of us (R.W.H.). We have expanded this study to include all records known to us for stomatopods from the Carolinas as well.

Five of the species reported here, *Cloridopsis dubia*, *Coronis scolopendra*, *Gibbesia (=Squilla) neglecta*, *Lysiosquilla scabricauda*, and *Squilla empusa*, frequent shallow, shore habitats (sensu Briggs 1961). The remainder of the species occur in offshore, sublittoral shelf habitats, several having been collected around Gray's Reef. One shore species, *Cloridopsis dubia* (Milne Edwards), has been taken only three times in Georgia since the late 1800s (see below, under species account). All but one of the species reported from the Carolinas by Lunz (1935) also are known from Georgia; Lunz included records for one species, *Lysiosquilla*

scabricauda (Lamarck), not yet known from Georgia.

Lysiosquilla scabricauda can be expected to occur in shallow habitats near shore as it and *Coronis scolopendra* commonly occur together in the Indian River estuary on the east coast of central Florida (R.B.M., personal observation). There, both of these stomatopods are abundant in shore habitats that they share with two callianassids that also are common in shallow water habitats in Georgia, *Biffarius biformis* (Biffar 1971) and *Callichirus major* (Say 1818).

Lysiosquillina glabriuscula, often found near coral reefs, can be expected to occur in the Gray's Reef area offshore where *Bigelowina biminiensis* appears to be rather common. Wenner et al. (1983) reported on the invertebrates associated with hard bottom habitats, like Gray's Reef, in the South Atlantic Bight; their collections included no stomatopods.

Three species, *Neogonodactylus torus*, *Coronis scolopendra*, and *Meiosquilla quadridens*, have not been recorded previously from Georgia, although Georgia is within their known range. Two species, *N. torus* and *M. quadridens*, have not been recorded previously from South Carolina. Three other species, *Bigelowina biminiensis*, *Heterosquilloides armata* and *Lysiosquilla scabricauda*, have not been recorded previously from off North Carolina.

Two other species, *Eurysquilla plumata* (Bigelow 1901) and *Heterosquilloides insolita* (Manning 1962), have been reported from shelf habitats off the east coast of Florida or in the Gulf of Mexico by Manning (1969) and Camp (1973) and might well occur on the continental shelf off the Carolinas and Georgia. They are not included

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in the key given below. The only other species known to occur off the east coast of the United States north of Florida is *Nannosquilla grayi* (Chace).

Gore and Becker (1976) reported 17 species from the central eastern coast of Florida, of which eight also occur in the Carolinean region to the north: *Cloridopsis dubia*, *Gibbesia neglecta* (as *Squilla neglecta*), *Heterosquilloides armata*, *Lysiosquilla scabricauda*, *Meiosquilla quadridens*, *Neogonodactylus wennerae* (as *Gonodactylus bredini*), *Squilla deceptrix*, and *S. empusa*. Field work by one of us (R.B.M.) on the central east coast of Florida added another species, *Coronis scolopendra*, and a nineteenth species, *Nannosquilla whitingi*, was added by Camp and Manning (1982), so that 10 of the 19 species known from the central east coast of Florida also occur to the north.

Seven of the 13 species reported by Camp (1973) from the west coast of central Florida also are known from the Carolinas and Georgia: *Bigelowina biminiensis*, *Gibbesia neglecta*, *Lysiosquilla scabricauda*, *Meiosquilla quadridens*, *Neogonodactylus wennerae*, *Squilla deceptrix*, and *Squilla empusa*. A fourteenth species, *Coronis scolopendra*, has been taken by one of us (R.B.M.) off the central west coast of Florida, so eight of the 14 species known from that area also occur off the Carolinas and Georgia.

Manning (1974a) summarized the stomatopod fauna of the northeastern United States and provided information on the four species that occurred in this temperate region. Three of the four, *Heterosquilloides armata*, *Platysquilloides enodis*, and *Squilla empusa*, also are found off North Carolina. The fourth species, *Nannosquilla grayi* (Chace 1958) appears to be a northern form currently known only from Massachusetts waters.

MATERIAL AND METHODS

Sources of material include: South Carolina Wildlife and Marine Resources Department, Marine Resources Research Institute, Charleston (MRRI) ; South Atlantic Benchmark Program (SABP); Savannah Science Museum (SSM).

Repositories include: Florida Marine Research Institute, St. Petersburg (FSBC); Nationaal Natuurhistorisch Museum (formerly Rijksmuseum van Natuurlijke Historie), Leiden, The Netherlands (RMNH); Museum of Natural History, University of Georgia, Athens (UG); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM).

Additional abbreviations used include: aw = abdominal width at fifth somite = AWCLI, abdominal width-carapace length index (aw/cl x 100); cl = carapace length; cm = centimeters; ft = feet; GMR = Georgia Marine Resources; leg.= collector or collected by; m = meters; mm = millimeters; sta = station; tl = total length.

The measurement given after the number and sex of specimens in the material section is total length (tl), measured on the midline; in some cases carapace length (cl), also measured on the midline, is given instead of total length.

RESULTS

Key to Stomatopod Crustacea From the Carolinas and Georgia

1. Telson with distinct dorsal median carina. Propodi of 3rd & 4th maxillipeds slender, longer than broad, not beaded or ribbed ventrally 2
Telson lacking distinct dorsal median carina. Propodi of third and fourth maxillipeds distinctly broader than long, beaded or ribbed ventrally. [Lysiosquilloidea] 8
2. Dactylus of claw unarmed. Propodus of claw lacking pectinations on opposable margin, propodus and dactylus inflated at their articulation. Telson with no more than 2 intermediate denticles (Gonodactyloidea, genus *Neogonodactylus*) 3
Dactylus of claw with teeth. Propodus of claw with pectinations on opposable margin, propodus and dactylus not inflated at their articulation. Telson with 4 or more intermediate denticles. [Squilloidea] ....
....4
3. Telson of *oerstedii* type, apices of intermediate marginal teeth sharp, separated from lateral edge of submedian teeth by distinct gap. Movable apices of submedian teeth usually present in adults .... *Neogonodactylus torus*
Telson of *bredini* type, apices of intermediate marginal teeth blunt, appressed to lateral edge of submedian teeth. Movable apices of submedian teeth usually absent in adults .... *Neogonodactylus wennerae*, new species 4. 3 or 4 epipods present. Submedian teeth of telson usually with movable apices or their sockets (except in some very large specimens of *C. dubia*) 5
5 epipods present. Submedian teeth of telson with fixed apices 6
5. 3 epipods present. Eyes flask-shaped, broad proximally, narrowing adjacent to very small cornea. Dactylus of claw with 5-6 teeth. Anterior 5 abdominal somites with submedian carinae .....*Cloridopsis dubia*
4 epipods present. Eyes T-shaped, broadest at cornea. Dactylus of claw with 4 teeth. Anterior 5 abdominal somites lacking sub-median carinae ·
.... *Meiosquilla quadridens*

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6. Mandibular palp absent. Dactylus of claw with 5 teeth. Lateral process of fifth thoracic somite spatulate ....*Gibbesia neglecta*
Mandibular palp present. Dactylus of claw with 6 teeth. Lateral process of fifth thoracic somite a curved spine, apex sharp. [Genus *Squilla*] 7
7. Median carina of carapace lacking anterior bifurcation. Telson with numerous dorsal tubercles...
....*Squilla deceptrix*
Median carina of carapace with distinct anterior bifurcation. Telson lacking dorsal tubercles....................
....*Squilla empusa*
8. Distal segment of endopod of anterior two walking legs elongate, strap-shaped. Proximal portion of outer margin of uropodal endopod lacking triangular fold 9
Distal segment of endopod of anterior two walking legs ovate or subcircular. Proximal portion of outer margin of uropodal endopod with distinct triangular fold 12
9. Marginal teeth of telson indistinguishable from other marginal armature. Telson lacking movable marginal teeth. Size very large, total length to at least 300 mm. [Genera *Lysiosquilla* and *Lysiosquillina* 10
Marginal teeth of telson distinct. Telson with movable apices on submedian marginal teeth..........11
10. Posterior margin of posterior two abdominal somites and dorsal surface of telson spinulose. Antennal scale strap-shaped, edged in dark pigment .... *Lysiosquilla scabricauda*
Posterior margin of posterior two abdominal somites and dorsal surface of telson smooth. Antennal scale oval, with central patch of dark pigment ....
....*Lysiosquillina glabriuscula*
11. Telson with 4 pairs of fixed marginal teeth, inner 2 pairs spatulate. Posterior margin of sixth abdominal somite and dorsal surface of telson without spinules ....,...................................*Platysquilloides enodis*
Telson with 2 pairs of fixed marginal teeth. Posterior margin of sixth abdominal somite and dorsal surface of telson spinulose .... *Heterosquilloides armata*
12. Rostral plate cordiform. Telson with 1 pair of fixed marginal teeth (laterals).... *Coronis scolopendra*
Rostral plate rectangular. Telson with more than 1 pair of fixed marginal teeth 13
13. Mandibular palp present. 5 epipods present. Dorsal surface of telson with fan-shaped, transverse row of 5 posterior spines ...... *Bigelowina biminiensis*
Mandibular palp absent. 4 epipods present. Posterior false eave on margin of telson unarmed posteriorly .... [Genus *Nannosquilla*] 14

14. Inner spine of basal prolongation of uropod longer than outer. Anterolateral corners of rostral plate rounded. Lateral most marginal tooth of telson placed on margin on each side, remainder submarginal .... *Nannosquilla whitingi*
Spines of basal prolongation of uropod subequal. Anterolateral corners of rostral plate acute. Lateral most 2 marginal teeth of telson placed on margin on each side, remainder submarginal ....
....*Nannosquilla carolinensis*

An illustrated, electronic version of the above key is available on diskette in Adobe Acrobat™ format with a free Acrobat reader. Anyone interested in obtaining a copy of this key should contact the senior author directly.

Superfamily Gonodactyloidea Giesbrecht 1910
Family Gonodactylidae Giesbrecht 1910
Neogonodactylus torus (Manning 1969)
Figure 1.

Gonodactylus torus Manning 1969:335, Figure 90 [type locality off Palm Beach, Florida, depth 73-91 m; North Carolina, depth 46 m, to Panama].

Neogonodactylus torus.-Manning 1995:80 [transferred from *Gonodactylus*].

Material. North Carolina: 34°6.9'N, 76°11.5'W, 100 m, leg. *Eastward*, 7 Oct 1966:1♂1♀, (not measured)(RMNH).- Georgia: 31° 32'06"N, 79°44'06"W, depth 58 m, leg. MRRI, 29 Oct. 1981:1♂ 18.5 mm, 1♀, 17.0 mm (USNM 232669).
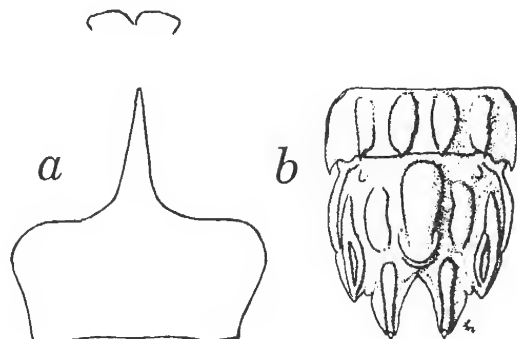
Figure 1. *Neogonodactylus torus* Manning. a, rostral plate and ocular scales; b, sixth abdominal somite and telson. (a from Manning & Hart 1981: Figure 2h; b from Manning 1969:Figure 90b).

Remarks. This species has not been recorded previously from off Georgia. There are no records of this species from off South Carolina. Manning (1995) recognized the genus *Neogonodactylus*, type species *Gonodactylus oerstedii* Hansen 1895 by original designation, for all of the American species previously assigned to *Gonodactylus*. The latter genus was restricted to five large species from the Indo-West Pacific region.

Neogonodactylus wennerae, new species
Figures 2, 3

Gonodactylus oerstedii. Lunz 1935:152, Figure 1 [off Cape Fear and off Beaufort, North Carolina; off Charleston Harbor, South Carolina].[Not *G. oerstedii* Hansen 1895.]

Gonodactylus oerstedi. Pearse and Williams, 1951:144 [Beaufort, North Carolina].[Not *G.oerstedii* Hansen 1895.]

Gonodactylus bredini. Manning 1969:315, Figure 88a-c [part; off North Carolina, including off New River and Beaufort, depths 27-35 m; off Charleston and Blackfish Banks, 12 miles off Charleston, South Carolina, and in depth of 33 m; off Georgia, depth 25 m; and Gulf of Mexico, off west coast of Florida]. Camp 1973:53, Figures 21-26, pl. 1 [color] [west coast of central Florida, depth 6-73 m]. Gore and Becker, 1976:154, 155, 156, 157, 159, 171 [part, offshore material only, east coast of central Florida, depth 13-40 m]. Morgan and Goy 1987:595-618 [larval development; off Frying Pan Shoals, North Carolina, depth 28 m].

Material. Holotype: South Carolina: 32°49'18"N, 78°39'24"W, depth 34 m, leg. MRRI, 3 Nov 1981: 1♀, 40 mm (holotype, USNM 232666). **Paratypes**:North Carolina: 34°23' 18"N, 76°33'48"W, depth 18 m, leg. Duke University, 10 Nov 1981: 1♀, 44 mm (USNM 221022). South Carolina: 32°50'24"N, 78°35' 48"W, depth 36 m, leg. R/V *Dolphin*, 20 Sep 1979: 2♂♂ 24 and 29 mm (USNM 186108). 32°50'06"N, 78°36'18"W, depth 35 m, leg. R/V *Dolphin*, 21 Sep 1979: 4♀♀ 27-35 mm, 2♀♀ both 30 mm (USNM 188106). 32°50'06"N, 78°35' 48"W, depth 36 m, leg. R/V *Dolphin*, 20 Sep 1979: 1♂ 34 mm, 2♂♂ 25 and 35 mm (USNM 188105).-32°50'12"N, 78°36'18"W, depth 35 m, leg. R/V *Dolphin*, 21 Sep 1979: 1♀, 26 mm (USNM 186109). 32°49'48"N, 78°36'W, depth 35 m, leg. R/V *Dolphin*, 21 Sep 1979: 2♂♂ 22 and 27 mm (USNM 188107). 32°49'30"N, 78°39'18"W, depth 34 m, leg. MRRI, 3 Nov 1981: 1♂ 20 mm (USNM 232667). 32°48'24"N, 78°39'36"W, depth 33 m, leg. MRRI, 28 Feb 1981: 1♀,12 mm (USNM 232653). 32°49'24"N, 78°39'12"W, depth 33 m, leg. MRRI, 27 Feb 1981: 1♀, 34 mm (USNM 232654). 32°49'18"N, 78°40'W, depth 33 m, leg. MRRI, 8 Aug 1981: 1♂ 29 mm (USNM 232661). 32°49'18"N, 78°39'42"W, depth 33 m, leg. MRRI, 28 Oct 1981: 1♀, 34 mm (USNM 232668).-32°49'12"N, 78°39'42"W, depth 33 m, leg. MRRI, 8 Aug 1981: 1♂ 32 mm (USNM 232663). 32°49'12"N, 78°39'42"W, depth 33 m, leg. MRRI, 8 Aug 1981: 1♀, 29 mm (USNM 232662).-32°49'06"N, 78°40'W, depth 34 m, leg. MRRI, 28 Feb 1981: 2♂♂ 12 and 19 mm, 1♀, 27 mm (USNM 232655). 31°44'06"N, 80°13'06"W, depth 33 m, leg. MRRI, 21 Feb 1980: 1♂ 14 mm (USNM 221023).-32°40'N,
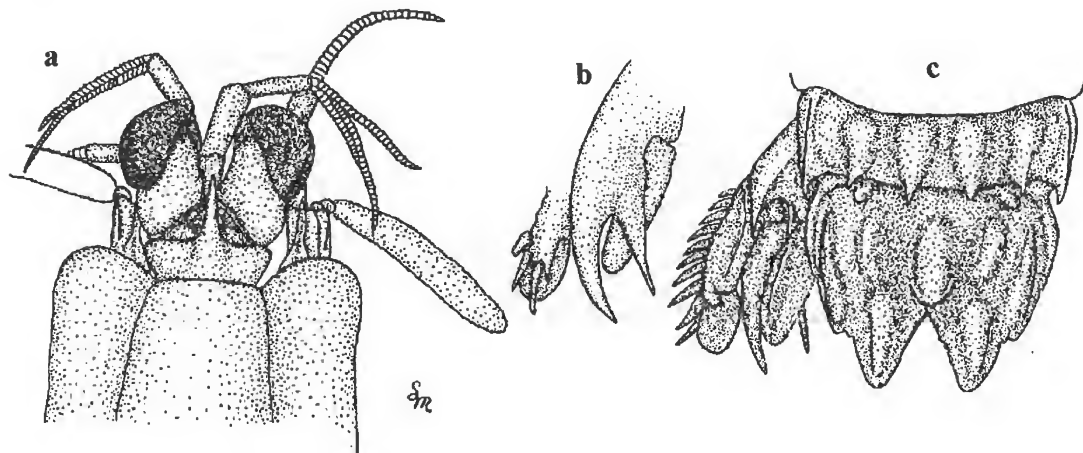
Figure 2. *Neogonodactylus wennerae*, new species. Off South Carolina, (holotype, tl 40 mm, USNM 232666. a, anterior part of body; b, uropod, ventral view; c, sixth abdominal somite, telson, and uropod.

78°47'W, depth 37 m, leg. SABP, 18 Aug 1977: 1♂ 16 mm, 3♀♀ 19-42 mm (USNM 174489). 32°40'N, 78°47'W, depth 37 m, leg. SABP, 18 Nov 1977: 1♂ 20 mm (USNM 174818).-32°30'54"N, 79°42'54"W, depth 20 m, leg. MRRI, 14 Mar 1984: 1♀, 13 mm (USNM 224095). 32°14'12"N, 79°45'06"W, depth 24 m, leg. R/V *Dolphin*, 2 Sep 1979: 2♂♂ 35 and 46 mm, 4♀♀ 34-42 mm (USNM 188104). Georgia: 31°41'18"N, 80°20'42", depth 27 m, leg. GMR, 23 Oct 1981: 1♀ 32 mm (USNM 232664). 31°41'12"N, 80°20'30"W, depth 27 m, leg. GMR, 9 Mar 1981: 1♀ 14 mm (USNM 232658). 31°41'06"N, 80°20'36"W, depth 28 m, leg. GMR, 9 Mar 1981: 1♀, 29 mm (USNM 232657). 31°41'06"N, 80°20'48"W, depth 28 m, leg. GMR, 9 Mar 1981: 1♀, 46 mm (USNM 232659).- 31°41'N, 80°20'36"W, depth 27 m, leg. GMR, 29 Apr 1981: 1♀, 26 mm (USNM 232660). 31°40'54"N, 80°20'54"W, depth 27 m, leg. GMR, 24 Oct 1981: 1♀, 46 mm (USNM 232665). 31°23'24"N, 80°53'24"W, depth 17 m, leg. GMR, 4 Mar 1981: 1♂ 46 mm (USNM 232656).-Sta 354, 30°48'47"N, 80°08'30"W, depth 143 ft (= 44 m), leg. M. Gray, 12 Sep 1963: 1♀, 18 mm (UG).-Sta 64, Sapelo whistle [buoy] 342° 3 miles, depth 58 ft (= 18 m), leg. M. Gray, 8 Nov 1961: 1♂ 39 mm (UG).- Sta 272, 30°52'02"N, 80°01' 14"W, depth 175 ft (= 53 m), tumbler dredge, leg. M. Gray, 23 Mar 1963: 1♂ 42 mm, 1♀, 36 mm (UG).

All specimens other than the holotype are paratypes.

Diagnosis. Size small, total length of adults less than 50 mm. Rostral plate as long as or slightly longer than broad, anterior spine appearing very elongate, spine about 1.5 times length of proximal, basal part of plate; anterolateral corners of plate acute but not sharp, slightly produced anteriorly. Ocular scales small, flattened dorsally, wider than high. Anterior five abdominal somites unarmed; sixth abdominal somite with 6 carinae, all usually armed posteriorly with sharp spine. Male (N=12) AWCLI 750-851, mean 796; female (N=18) AWCLI 775-893, mean 839. Telson as long as broad, of *bredini* type, lacking dorsal tubercles; carinae of telson well defined, all unarmed; anchor often with posterior median tubercle; knob inconspicuous.

Size. Males and females, tl 12-46 mm. Other measurements of female holotype, tl 40 mm: rostral plate length, width both 2.7 mm; carapace length 9.1 mm; fifth abdominal somite width 8.1 mm; telson length, width both 7.0 mm.

Remarks. In addition to habitat (sublittoral vs. shore) and their smaller size (specimens of *N. bredini* from the Caribbean may exceed 70 mm in length as adults), specimens of *N. wennerae* differ from *N. bredini* in having a much longer rostral spine, with the basal part of the plate correspondingly shorter. Camp (1973:Figures 21, 25) clearly showed the long rostral spine of specimens from the
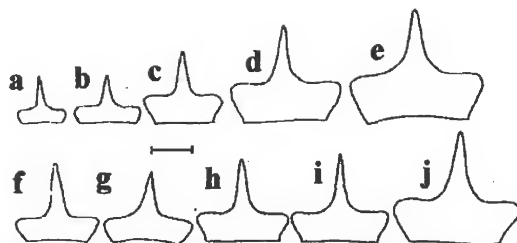
Figure 3. *Neogonodactylus wennerae*, new species. Outlines of rostral plates of males (a-e) and females (f-j) at different total lengths. a, 12 mm, b, 18 mm, c, 28 mm; d, 35 mm, e, 46 mm; f, 25 mm, g, 27 mm; h, 29 mm; i, 30 mm; j, 42 mm. Scale = 1 mm.

Gulf of Mexico. That the rostral spine in *N. wennerae* is relatively long at all sizes is evident from Figure 3, where the rostral plates of males and females of different sizes are illustrated. All of the specimens identified here as *N. wennerae* represent the sublittoral form of *N. bredini* (Manning 1969) reported by Manning (1969) from off North Carolina, northeastern Florida and the Gulf of Mexico and reported by Camp (1973) based on material collected sub-littorally in the Gulf of Mexico. The larval development of *N. wennerae* was described by Morgan and Goy (1987), who pointed out that differences between members of the population from Bermuda and that from North Carolina suggested they represented different species.

Etymology. Named for our colleague and friend Elizabeth L. Wenner, South Carolina Marine Resources Research Institute, whose research has added significantly to our knowledge of the larger crustacean fauna of the Carolinean shelf area. Most of our specimens from off South Carolina, including the holotype, were taken during her field studies.

Superfamily Lysiosquilloidea Dana 1852
Family Heterosquillidae Manning 1995
Heterosquilloides armata (Smith 1881)
Figures 4, 5

Lysiosquilla armata Smith 1881:446 [type locality off Martha's Vineyard, Massachusetts, depth 65 and 120 fms (119 and 220 m)].

Heterosquilla(Heterosquilloides) armata.- Manning 1969:52, Figure 11 [Off New England, depth 96-218 m]. Gore and Becker, 1975:22, Figures 1-3 [off New Jersey, depth 128 m; off east coast of central Florida, depth 210 m]; 1976:148, 155, 160 [off east coast of central Florida, depth 210 m].

Heterosquilloides armata.- Camp, 1985: 465, Figure 1 [off New Jersey, depth 139 m; off Galveston, Texas, depth 121-181 m].
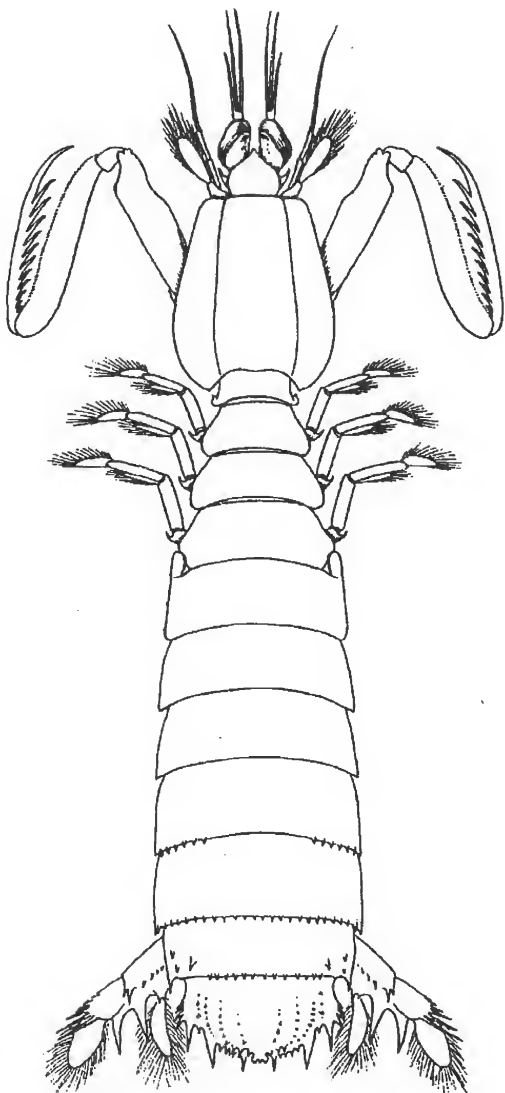
Figure 4. *Heterosquilloides armata* (Smith). Dorsal view. (from Manning 1969:Figure 11a).

Figure 5. *Heterosquilloides armata* (Smith). Off Cape Hatteras, (postlarva, tl ca. 9 mm. a, sixth abdominal somite, telson, and uropod; b, uropod, ventral view.
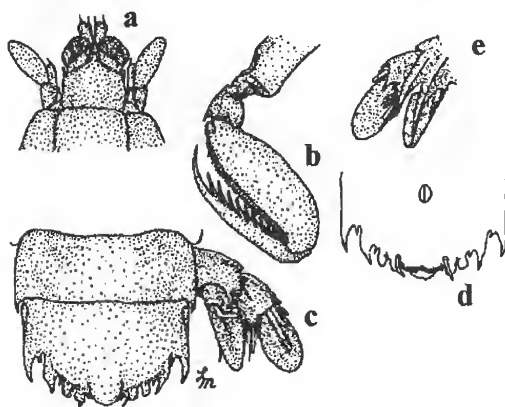
Figure 6. *Platysquilloides enodis* (Manning). a, anterior part of body; b, claw; c, sixth abdominal somite, telson, and uropod; d, telson, ventral view; e, uropod, ventral view. (from Manning & Camp 1981:Figure 2).

condition in the adult, in which the spines of the basal prolongation of the uropod are subequal, in the juvenile the inner spine is distinctly longer than the outer. The species is now known to occur in outer shelf depths from New England to Texas. It has not been recorded previously from North Carolina.

Material. North Carolina: Off Cape Hatteras, 35°39'N, 74°50'W, leg. R/V *Delaware II*, cruise 70-7, sta 26, depth not given, from stomach of a butterfish, 9 Sep 1970: 1(postlarva, tl ca. 9 mm, cl 1.9 mm, in poor condition (USNM 173096).

Remarks. This postlarva (Figure 5) is clearly identifiable with *H. armata*, as the movable spines on the uropodal exopod are all slender and evenly curved. None is spatulate and slightly recurved as in *Platysquilloides enodis*. Unlike the

Platysquilloides enodis (Manning 1962)
Figure 6.

Lysiosquilla enodis Manning, 1962:220 [type locality off Vineyard Sound, Massachusetts, depth 31-49 m; off North Carolina, depth 49 m].

Platysquilla enodis. Manning 1969:91, Figure 25 [off Vineyard Sound, Massachusetts, depth 31-49 m; off North Carolina, depth 49 m]. Howells et al., 1980:101 [Off New Jersey, Maryland, and Virginia, depth 33-41 m].

Platysquilloides enodis. Manning and Camp 1981: Figure 2 [off New Jersey].

Family Lysiosquillidae Dana 1852
Lysiosquilla scabricauda (Lamarck 1818)
Figures 7. a,b

Squilla scabricauda Lamarck 1818:188 [type locality l'Ocean Indien]. Gibbes, in Tuomey, 1848:xvi [South Carolina]; 1849:22 [Georgia]; 1850:199 [off Charleston Harbor, South Carolina]. Howard 1883:294 [South Carolina].

Lysiosquilla scabricauda. Lunz 1935:154 [off Charleston Harbor, South Carolina]. Manning 1969:24, Figures 2-4, 5a,b [Bermuda to Brazil]. Camp 1973:10, Figure 2 [west coast of central Florida, depth 55 m]. Gore and Becker, 1976:152, 153, 160, Figure 3 [east coast of central Florida, surface, subtidal, and at 10 m]. Wenner and Wenner 1989:160 [Carolinean shelf].

Material. North Carolina: Off Frying Pan Shoals, 33°45'N, 77°30'W, depth 85 ft (= 26 m), fish trap, 9 Sep 1976: 1♂ 271 mm (USNM 168867).

Remarks. This is the first record for the species from North Carolina. It apparently is not at all common in localities north of Florida.

Lysiosquillina glabriuscula (Lamarck, 1818)
Figure 7. c,d

Squilla glabriuscula Lamarck 1818:188 [type locality l'Ocean Indien].

· *Lysiosquilla glabriuscula*.-Sharp, 1893: 106 [Hilton Head, South Carolina; Florida].-Bullis and Thompson 1965:13 [South Carolina, depth 40 m].-Manning 1969:34, Figures 5c,d, 6 [Hilton Head, and off South Carolina, depth 40 m; Bahamas and Florida to Brazil].

Lysiosquillina glabriuscula. Manning 1995: 133 [transferred from *Lysiosquilla*].

Material. South Carolina: 32°49'18"N, 78°39'42"W, depth 33 m, leg. MRRI, 28 Oct 1981: 1 juvenile ♂ damaged, cl. 5.1 mm (USNM 221026).

Remarks. This species has not been recorded from North Carolina or Georgia and appears to be rare off South Carolina. Manning (1995) recognized the genus *Lysiosquillina* for three species previously assigned to *Lysiosquilla*, *L. glabriuscula* and two Indo-West Pacific species.

Family Nannosquillidae Manning 1980
Bigelowina biminiensis (Bigelow 1893)
Figure 8.

Lysiosquilla biminiensis Bigelow 1893 b:102 [type locality Bimini, Bahamas].

Acanthosquilla biminiensis. Manning 1969:63, Figures 14, 15 [Bahamas, Florida, Gulf of Mexico, Caribbean,
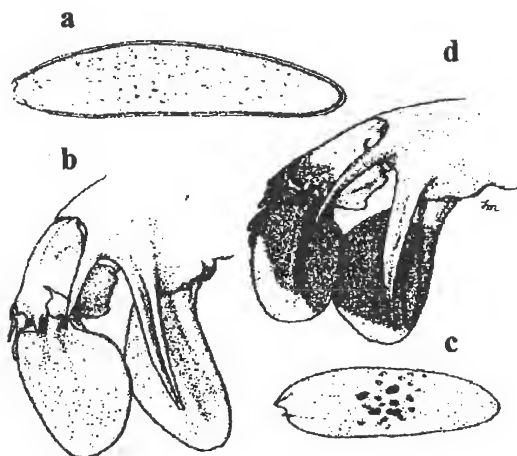
Figure 7. a,b. *Lysiosquilla scabricauda* (Lamarck). a, antennal scale; b, uropod, ventral view (from Manning 1969: Figure 5a,b). Figure 7 c,d. *Lysiosquillina glabriuscula* (Lamarck). c, antennal scale; d, uropod, ventral view (from Manning 1969: Figure 5c,d).

Brazil]. Camp, 1973:11, Figures 3, 4 [west coast of central Florida, depth 8 and 18 m].

Bigelowina biminiensis.-Schotte and Manning, 1993:574, Figure 4 [South Carolina, depth 37 m; Georgia, depth 14, 34, and 46 m; and northeastern Florida, depth 15 m; Tobago].

Material. North Carolina: 34°12'30"N, 76°07'48"W, depth 65 m, R/V *Eastward* sta 5962: 1♀, cl 10.5 mm (USNM 120228). South Carolina: 32°40'N, 78°47'W, depth 37 m, SABP, 18 Nov 1977: 1 juvenile (probably a postlarva), ca. 10 mm (USNM 174488). Georgia: Sta 335, 31°44'55"N, 80°49'51"W, depth 53 ft (= 16 m), bucket dredge, leg. M. Gray, 21 Aug 1963: 1 fragment (UG). 31°08'N, 80°50'W, depth 14 m, SABP, 25 Feb 1977: 3 juveniles, 8.5-13 mm (USNM 174484).-Sta 201, Sapelo Island, 31°06'N, 80°32'W, depth 96 ft (= 29 m), leg. Darby and Gray, 6 May 1963: fragments of 1 specimen (UG). 31°03'N, 80°26'W, depth 34 m, SABP, 24 Nov 1977: 1♀, 25 mm (USNM 174486).-30°59'N, 80°08'W, depth 46 m, SABP, 30 Aug 1977: 1♀, 12.5 mm (USNM 174487). Sta 246, 30°57'36"N, 80°55'W, depth 69 ft (= 21 m), leg. M. Gray, 23 Jul 1963: 1 juvenile, cl 9.5 mm (UG). Sta 376, Sapelo Island whistle buoy 320° 4.5-5 miles, depth 65 ft (= 20 m), leg. M. Gray, 19 Oct 1963: 1♀, 29.5 mm (UG). Sapelo Island, 3 miles south of whistle buoy, 16 miles east of island, sponge reef area, 2 Sep 1969: 1♂ 17.5 mm (USNM 128350).
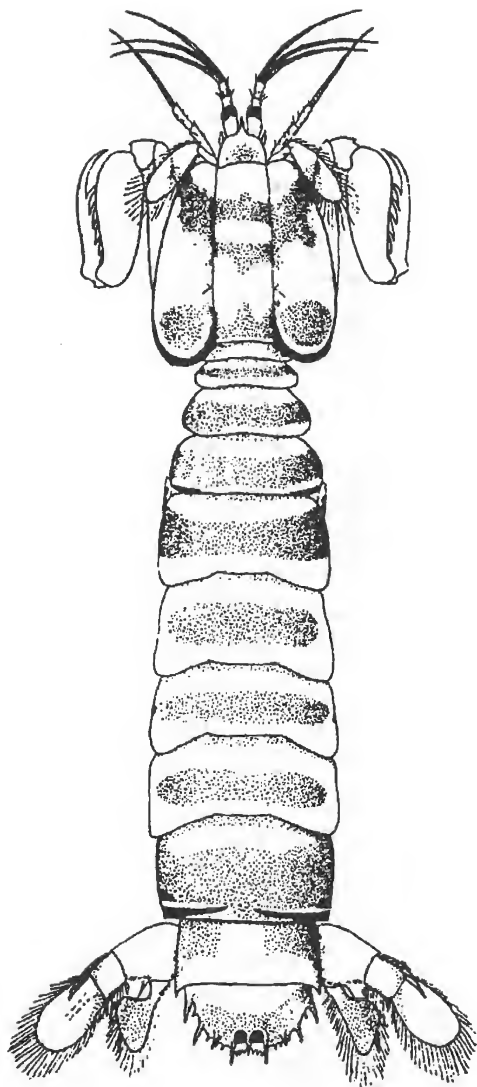
Figure 8. *Bigelowina biminiensis* (Bigelow). Dorsal view (from Manning 1969:Figure 14).

Remarks. This species appears to be a rather common component of the sublittoral habitats off Georgia, where it probably occurs in a restricted, specific type of substrate. Very large specimens, like the female from North Carolina with a carapace length of 10.5 mm, have a distinct mesial tubercle on the cornea. This is the first record for the species from North Carolina.

Coronis scolopendra **Latreille 1828**
Figure 9.

Coronis scolopendra Latreille 1828:474 [type locality Brazil]. Manning 1969:88, Figure 24 [Brazil]. Manning and Reaka 1989:213-219, Figures 1-4 [east coast of central Florida]. Rodrigues and Manning 1992:79-82, Figure 1 [larva; Brazil].

Lysiosquilla. Brooks 1885:10, 11 [Beaufort, North Carolina]; 1886a:166, 167, 168 [Beaufort, North Carolina]. Pearse et al., 1942: 144, 147, 148, 151, 153, 155, Figure 10 [Bird and Sheepshead Shoals and Fort Macon Beach, North Carolina].

Lysiosquilla excavatrix. Brooks 1886b:21, 51 [Beaufort, North Carolina]. Pearse et al. 1942:185, Figure 13 (Bird Shoal, on flat beaches, and outside Fort Macon, North Carolina]. Fox and Ruppert, 1985:316 [listed].
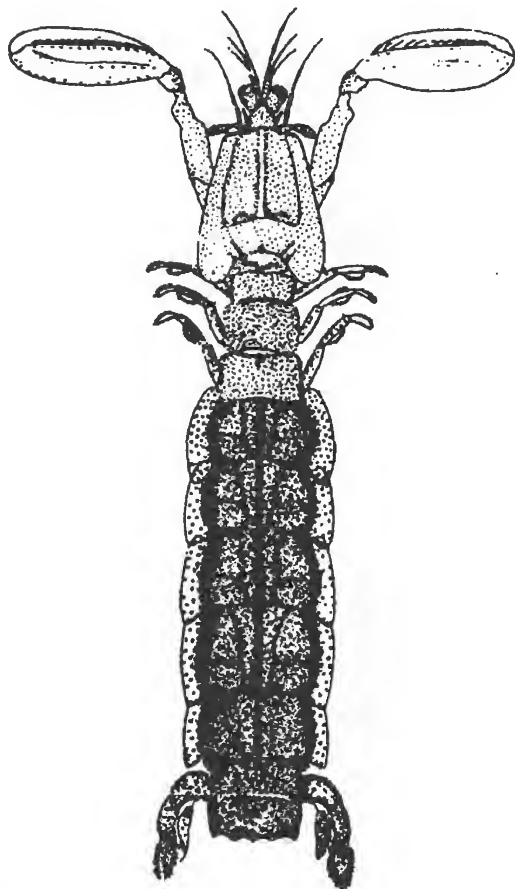
Figure 9. *Coronis scolopendra* Latreille. Dorsal view (from Brooks 1886b:pl. 10, Figure 8).

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Lysiosquilla (Coronis) excavatrix Brooks, 1886b:48, 101, pl. 10, Figures 8-16 [adult], pl. 11, Figures 1-3 [larva] [type locality Beaufort, North Carolina].

Coronis excavatrix. Lunz, 1935:153, Figure 2 [Beaufort, North Carolina]. Manning 1969:84, Figures 22, 23 [Bogue Banks and Bird Shoal, Fort Macon; Fort Macon; Sheepshead Shoal; and Beaufort; all North Carolina; Gulf of Mexico from Mobile, Alabama to Port Aransas, Texas]. Boothe, 1977:163 [North Edisto River, South Carolina]. Fox and Ruppert, 1985:51, 121, 128, 187, 195, 258, 285, 316 [from beaches along South Carolina].

Material. North Carolina: Beaufort, H. W. Connley, Wesleyan University Collection #659: 1♂ 24 mm (USNM 150796). Buxton, at state campground on Route 30, caught by Hasty family on a fish hook, 13 Aug 1979: 1♀, 64 mm (USNM 181650). Onslow County, New River, spoil bank at east end of Courthouse Bay, leg. R. B. Manning and D. B. Bixler, 30 Jul 1989: 3♂♂, 28-55 mm, 1♀, 55 mm (USNM).- South Carolina: North end of South Creek, North Edisto River, leg. B. B. Boothe, 4 Mar 1976: 1♂ 22 mm (USNM 169199). Georgia: Southeast end of Sapelo Island, lower intertidal, leg. R. W. Heard, May 1988: 1♀, 23 mm, fragments of 4 juveniles (USNM). Tybee Island, Savannah Beach, tide pools, lower intertidal, sand bar, beach, leg. R. W. Heard, 8 Jul 1992: 3♂♂, 52-72 mm, 2(♀, 50-67 mm (USNM).

Remarks. Boothe (1977) recorded this species from South Carolina and Manning and Reaka (1989) reported it from the Indian River region of Florida. Its first larva was described by Rodrigues and Manning (1992).

Fox and Ruppert (1985) found this species to be common in all seasons but winter along protected beaches and southern open beaches of South Carolina. They reported that the burrows of this species were 1 cm across and (p 121) that the "holes open into straight, smooth-walled, usually rusty-brown, vertical shafts."

This species has not been recorded previously from Georgia, although that is well within its known range.

Nannosquilla carolinensis Manning 1970
Figure 10.

Nannosquilla carolinensis Manning 1970:99, Figure 1 [type locality off North Carolina, depth 100 m].-Camp and Manning 1986:6 [off South Carolina, depth 34 m].
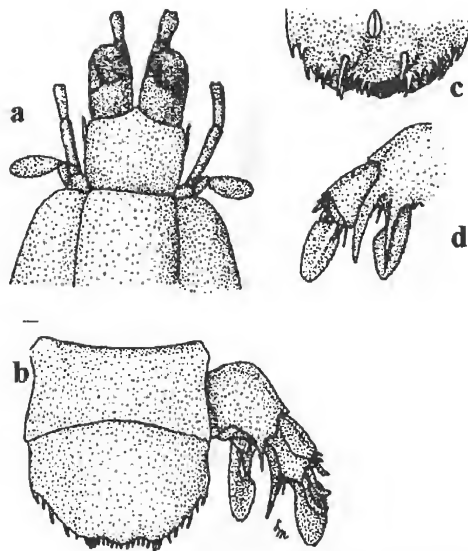
Figure 10. *Nannosquilla carolinensis* Manning. a, anterior part of body; b, sixth abdominal somite, telson, and uropod; c, telson, ventral view; d, uropod, ventral view. (from Manning 1970: Figure 1).

Nannosquilla whitingi Camp and Manning 1982
Figure 11.

Nannosquilla grayi. Manning 1969:78 [part, specimen from off Sapelo Island only]. [Not *Lysiosquilla grayi* Chace, 1958.]

Nannosquilla baliops Camp and Manning 1982:6, Figure 5 [type locality off Hutchinson Island, east coast of central Florida, depth 11 m]; 1986:15 [in key].

Nannosquilla whitingi Camp and Manning 1982:11, Figures 3e,f, 8, 9 [type locality off Hutchinson Island, east coast of central Florida, depths 8 and 11 m]; 1986:15 [in key].

Material. Georgia: Off Sapelo Island, Doboy Sound sea buoy 3 miles 274°, depth 15 m, leg. Frankenberg and Gray, 4 Feb 1963: 1 ♀, 27 mm (UG).

Remarks. Reexamination of this specimen, first identified by Manning (1969) with *Nannosquilla grayi* (Chace), has confirmed that it can be identified with *N. whitingi*, as suggested by Camp and Manning (1982). We also believe that *N. baliops* can be identified with *N. whitingi*. The only differences between *N. baliops* and *N. whitingi* are in the extent of pigmentation of the body. The only other offshore species of *Nannosquilla* is *N. carolinensis* Manning, known only from the Carolinas. That species differs from *N. whitingi* in having sharp posterolateral angles on the fifth abdominal somite, the
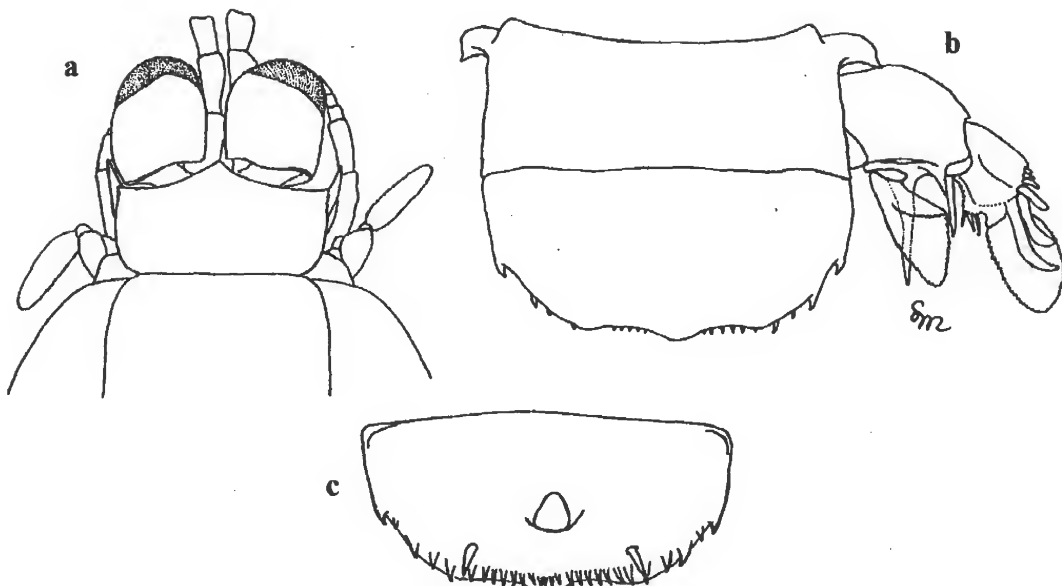
Figure 11. *Nannosquilla whitingi* Camp and Manning. Off Sapelo Island, ♀, tl 27 mm. a, anterior part of body; b, sixth abdominal somite, telson, and uropod; c, telson, ventral view.

spines of the basal prolongation of the uropod subequal in length, and two of the marginal teeth of the telson on the margin rather than just one tooth on the margin.

Superfamily Squilloidea Latreille 1803
Family Squillidae Latreille 1803
Cloridopsis dubia (Milne Edwards 1837)
Figure 12.

Squilla dubia Milne Edwards 1837:522 [type locality l'Amerique]. Gibbes, in Tuomey, 1848:xvi [South Carolina]; 1849:22 [Georgia]; 1850:200 [Charleston Harbor, South Carolina]. Howard 1883:294 [South Carolina]. Rathbun 1883:121-130 [Savannah, Georgia]. Bigelow 1894:518 [Charleston, South Carolina; Savannah, Georgia].

Chloridella dubia. Lunz 1935:157, Figure 5 [Charleston, South Carolina].

Cloridopsis dubia. Manning 1969:141, Figures 39b, 41 [Charleston, South Carolina; Savannah, Georgia; Florida to Brazil]. Gore and Becker, 1976:152, 153, 161, Figure 4 [east coast of central Florida; intertidal].

Material. South Carolina: Cherry Point, in mud at base of dock, leg. E. Morris, 14 Jun 1980: 1♂ cl 31 mm (FSBC I 59907). Georgia: Off Green Island, Chatham County, Ossabaw Sound, depth 4-5 m, bottom mud and sand, trawl, leg. G. Williamson, 21 Oct 1972: 1♂ cl 22.8 mm (USNM 274360).

Remarks. Manning (1968:128) and (1969:140), in diagnoses of *Cloridopsis*, stated that the submedian teeth of the telson had fixed rather than movable apices.
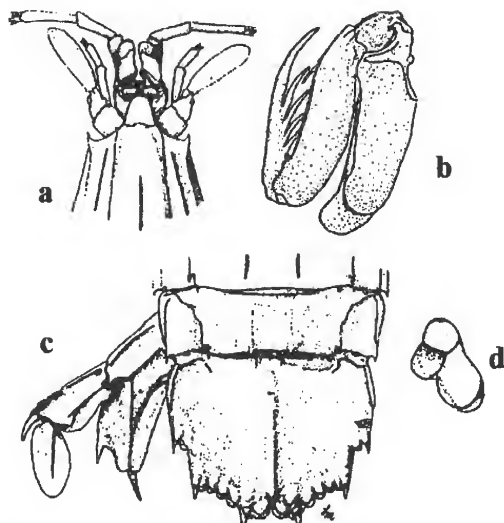
Figure 12. *Cloridopsis dubia* (Milne Edwards). a, anterior part of body; b, raptorial claw; c, posterior two abdominal somites, telson, and uropod; d, eye. (a,c,d from Manning 1969:fig. 41a,b,f; b, ♀, tl 103 mm, Miami, Florida, USNM 119184).

Manning (1974b:107, Figure 3) corrected this statement and pointed out that the movable apices were visible in smaller specimens and that their sockets were visible in larger specimens. Although the apices or sockets were visible in all specimens examined by us, they may not be detectable in very large specimens (David Camp pers comm). The specimen recorded here from Georgia is the first reported from that state since the last century. It could be much more common off the Carolinas and Georgia than indicated by the small number of recent records. Lunz (1935:157) noted that "although it occurs regularly at Charleston, it is by no means abundant." The species is not known to occur in North Carolina.

Gibbesia, new genus

Diagnosis. Size large, total length to more than 100 mm in adults. Eye large, cornea bilobed, inner margin of eye longer than outer. Ocular scales separate. Carapace with median carina. Mandibular palp absent. 5 epipods present. Dactylus of claw with 5 teeth, outer margin of dactylus sinuate. Lateral process of fifth thoracic somite a spatulate lobe. Lateral processes of sixth and seventh thoracic somites indistinctly bilobed, posterior lobe much the larger, bluntly rounded laterally. Abdominal somites 1-5 with 4 pairs of carinae, medians absent. Telson with median carina only. Apices of submedian teeth of telson fixed.

Type species. *Squilla neglecta* Gibbes 1850, by present designation and monotypy.

Etymology. Named for Lewis Reeve Gibbes (14 August 1810-21 November 1894) (Figure 13), chemist and naturalist, the author of the type species. Gibbes was a remarkable scientist whose interests extended from natural history to physics and chemistry. He was born at Charleston and was graduated from the Medical College of South Carolina in 1836. He subsequently studied in Paris, but he never practiced medicine, preferring research and teaching. He was professor in the College of Charleston from 1838 to 1892, where he occupied the chair in mathematics and also that of astronomy and physics. His expertise included astronomy, mathematics, chemistry, physics, botany, and zoology. Among his accomplishments was an early classification of the elements, his "Synoptical Tables of the Chemical Elements" (Taylor 1941; Weeks 1956). He is known to carcinologists primarily for his synopsis on the crustaceans in collections in the United States (1850), in which he named *Squilla neglecta*. A short biography was published by Porcher (1920) in American Medical Biographies.

Remarks. Members of *Gibbesia* can be distinguished from members of *Squilla* sensu Manning 1969 in that the
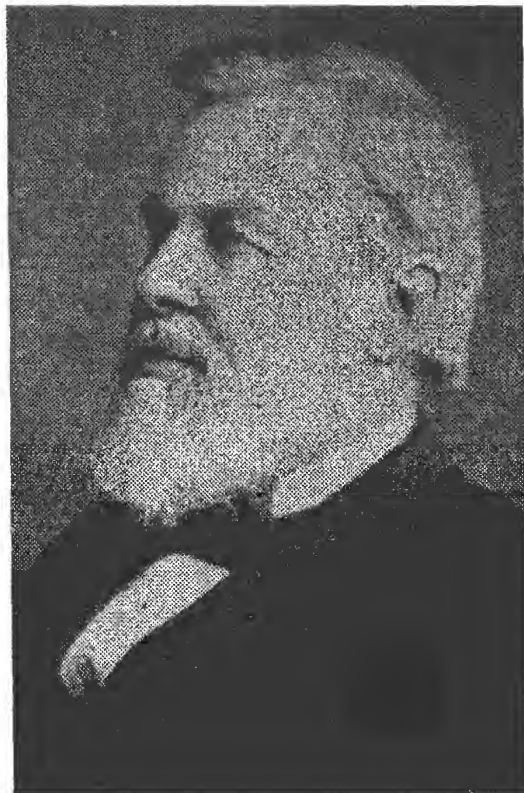
Figure 13. Lewis Reeve Gibbes, 14 August 1810-21 November 1894 (from Division of Crustacea files, USNM).

dactylus of the claw is armed with five rather than six teeth and the mandibular palp is completely suppressed. In their account of the genus *Fennerosquilla*, Manning and Camp (1983) noted that since Manning's (1968) restriction of *Squilla* to Atlanto-East Pacific species, several features, including the number of teeth on the claw and the presence or absence of the mandibular palp, are now recognized as important characters at the generic level. The recognition of *Gibbesia* here is based on these features, the most important of which is the condition of the mandibular palp.

Gibbesia neglecta (Gibbes, 1850), new comb.
Figure 14.

Squilla neglecta Gibbes, in Tuomey, 1848:xvi [South Carolina; nomen nudum]; 1849:22 [Georgia; nomen nudum]; 1850:200 [type locality Charleston Harbor, South Carolina]. Howard 1883:294 [South Carolina]; Lunz 1933:3, 4, 5 6 7, pl. 1 [Charleston Harbor, South Carolina];

1935:154, Figure 4 [Beaufort, North Carolina; Charleston Harbor, South Carolina]. Manning 1969:181, Figure 50b, 51 [off Cape Hatteras, North Carolina, depth 25 m; Isle of Palms, Charleston Harbor, off Kiawah Island and Rockville, South Carolina; off Sapelo Island, Georgia; and Florida to Brazil].-Dörjes 1972:190, Figure on pl. 1 [Sapelo Island, Georgia]. Camp 1973:37, Figure 13 [west coast of central Florida; depth 6 and 18 m]. Howard and Frey; 1975a:12 [Sapelo Sound, Georgia]. Gore and Becker, 1976:152, 156, 157, 158, 169, Figure 10 [east coast of central Florida; depths 10, 26, and 28 m]. Wenner and Wenner, 1989:159, 160, 161, 167, 172, fig. 4 [North Carolina to east coast of central Florida, depths 4-20 m].

Chloridella neglecta. Lunz 1935:154, Figure 4 [North Carolina].

Material. North Carolina: 5°07'12"N, 5°25'42"W to 35°06'48"N, 75°24'42"W, depth 23-25 m, leg. R/V *Gillis* sta 6, 13 Nov 1974: 1♀, 40 mm (USNM 151555). Southeast of Cape Hatteras, 4°31'N, 75°55'W, depth 35 fm (67 m), M/V *Combat* sta 396, 21 Jun 1957: 1♂ 93 mm (USNM 170198), 33°35'N, 8°05'W, depth 18 m, leg. SABP, 16 Aug 1977: 1♂, 100 mm, 1♀, 88 mm (USNM 174018). South Carolina: south end of Hilton

Figure 14. *Gibbesia neglecta* (Gibbes). Sapelo Island, ♀, tl 82 mm. a, anterior part of body; b, raptorial claw; c, lateral processes of exposed thoracic and first abdominal somites.

Head Island, Calibogue Sound, leg. Anderson, 15 Aug 1957: 1♀, 35 mm (USNM 153961). Georgia:[Ossabaw, Wassaw Sound, and St. Andrews Sounds, Leg. SSM],Wassaw Sound STERI sta. W-4-T, 14 May 1972:1♂ 23 mm (USNM). Wassaw Sound, STERI sta. W-7-T, 14 May 1972 3 ♀♀ 43-77 mm (USNM). Wassaw Sound, STERI sta. W-6-T, 19 Apr 1972 2 ♂♂, 52-65 mm, 1♀, 46 mm (USNM). Ossabaw Sound, STERI sta. O-2-T, 4 April 1972 1♀, 48 mm (USNM). Ossabaw Sound, STERI sta. O-1-T, 4 Apr 1972 1♀, 83 mm (USNM). Ossabaw Sound (off Pine Island), 13 May 1972 1♀, 44 mm (USNM). St. Andrews Sound (off Little Cumberland), 10 Jul 1974 1♀, 71 mm (USNM). 31°24'13"N, 81°09'44"W, depth 30 ft (9 m), leg. A.S. Leiper, sta 548, Sep 1970: fragments (UG). 31°23'18"N, 81°12'27'W, depth 28 ft (8.5 m), leg. A.S. Leiper, sta 553, Nov 1970: 1♀, 28 mm (UG). Same data, sta 544: 1♂, 16.5mm (UG). 31°05'27"N, 81°06'57"W, depth 35 ft (11 m), leg. A.S. Leiper, sta 549, Sep 1970: 1 juvenile, 13 mm (UG). Marsh Island, Sapelo, 27 Jul 1961: 7♂♂ 38-60 mm, 5♀♀ 27-42 mm (UG). Sapelo Beach, coming out of holes in sand, 28 Jul 1973: 1♂, 40 mm, 6♀♀ 30-38 mm (UG). Doboy Sound, Sapelo Island, shrimp trawl, leg. M. Gray, drag 7, 28 Jan 1961: 1♀, 82 mm (UG). South end of Nannygoat Beach, Sapelo Island, in mud, low tide, 7 Aug 1971: 1♂, 49 mm (UG). Off Sapelo Island, 6 miles 90° from sea buoy, depth 41 ft (= 12.5 m), leg. M. Gray, drag 52, 26 Oct 61: 1♀, 32 mm (UG).

Remarks. Characteristics of the species are clearly visible even in the smallest specimens examined. The specimens from Marsh Island were taken together with *S. empusa.* Only one specimen of *G. neglecta* was taken by Howard and Frey (1975a) on the Atlantic side of Sapelo Sound where the observed salinity ranged from 20.5-32.8 (mean 28.9). In contrast, 15 specimens of *S. empusa* were collected at the same station and a total of 120 specimens of the latter species were taken during their study. Wenner and Wenner (1989) reported that this species was found in 49% of the trawl tows they made in depths of 4 to 20 m between Cape Fear, North Carolina and Cape Canaveral, Florida. The number of individuals per tow was highest in substrates off Georgia in seasons other than winter, when none were found there.

Meiosquilla quadridens (Bigelow 1893)
Figure 15.

Squilla quadridens Bigelow 1893a:101 [type locality, Key Largo, Florida, depth 102 m].

Meiosquilla quadridens.-Manning 1969:106, Figures 31, 33a [North Carolina, depth 89 m; Bahamas and Florida
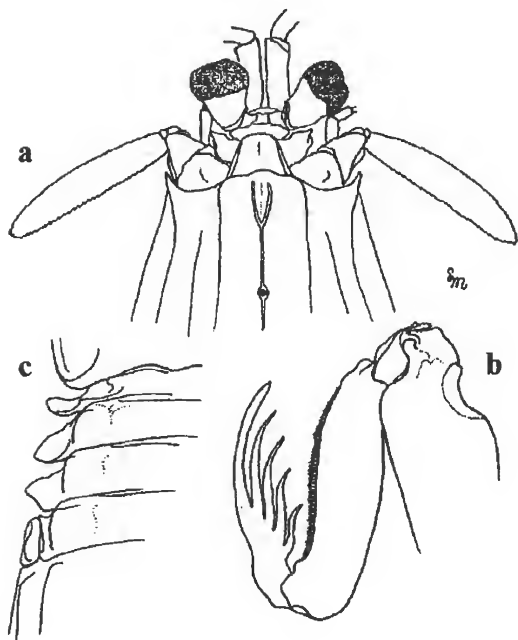
to Surinam]. Camp 1973:18, Figures 6, 7 [west coast of central Florida, depths 37, 55, and 73 m]. Gore and Becker, 1976:156, 158, 162, Figure 5 [east coast of central Florida, depths 50 and 64 m].

Material. South Carolina: 32°49'30"N, 78°39'42"W, depth 33 m, leg. MRRI, 3 Nov 1981: 1♂, 13.5 mm (USNM 232652). 32°49'24"N, 78°39'30"W, depth 33 m, leg. MRRI, 3 Nov 1981: 3♂♂ 11-12 mm (USNM 232649). 32°29'06'N, 78°49'18"W, depth 52 m, leg. MRRI, 6 Aug 1981: 1♀, 11.5 mm (USNM 221024). 31°32'N, 79°44'24"W, depth 56 m, leg. MRRI, 10 Mar 1981: 1♀, 17 mm (USNM 232651). 31°31'54"N, 79°44'24"W, depth 60 m, leg. MRRI, 8 Mar 1980: 1 fragment of ♂, cl 3.8 mm (USNM 221021). Georgia: 31°41'06"N, 80°20'48"W, depth 27 m, leg. GMR, 5 Nov 1981: 1 juvenile ♂, 12 mm (USNM 232650). 31°03'N, 80°26'W, depth 34 m, SABP, 16 May 1977: 1 juvenile ♂, 12 mm (USNM 174491).

Remarks. Both specimens from Georgia, although young, are clearly identifiable with *M. quadridens*, each having 4 epipods, rounded lateral processes on the sixth

Figure 15. *Meiosquilla quadridens* (Bigelow). a, anterior part of body; b, raptorial claw; c, posterior two abdominal somites, telson, and uropod. (a,c from Manning 1969:Figure 31a,d; b, (holotype, tl 23 mm, off Key Largo, Florida, USNM 11547).

and seventh thoracic somites, and short submedian carinae on the telson. This species has not been recorded previously from off South Carolina or Georgia.

Squilla deceptrix Manning 1969
Figure 16.

Squilla discors Manning 1962:217 [part - the original account included material of two species; North Carolina, depth 49 fms (90 m)].

Squilla deceptrix Manning 1969:165, figs. 44b, 46 [type locality off Panama, depth 137 m; North Carolina, depths 89 and 100 m; Florida and Caribbean, depths 49 to 309-346 m]. Camp 1973:1, 33, Figure 12 [west coast of central Florida, depths 37, 55, and 73 m].- Gore and Becker 1976:154, 156, 157, 158, 159, 164, fig. 7 [east coast of central Florida; depths 37, 40, 45, 48, 64, and 100-97 m].

Squilla empusa Say, 1818
Figure 17.

Squilla empusa Say 1818:250 [type locality Rhode Island]. Gibbes, in Tuomey, 1848:xvi [South Carolina]; 1849:22 [Georgia]; 1850:199 [Charleston Harbor, South Carolina]. Coues and Yarrow 1878:298 [Fort Macon, North Carolina]. Howard 1883:274 [South Carolina]. Brooks 1885:10, 11 [Beaufort, North Carolina]; 1886a:166, 168 [Beaufort, North Carolina]; 1886b:101, pl. 1, Figures 4, 5 [larva], pl. 2, Figure 7 [Beaufort, North Carolina]. Sharp 1893:107 [Beaufort, North Carolina; Hilton Head, South Carolina]. Lunz 1937:8 [mouth of Wilmington River and St. Simon's Sound, Georgia]. Manning 1969:201, Figures 57a, 58, 59 [Massachusetts to Surinam, including numerous localities off the Carolinas and Georgia, depths 9-55 m, usually less than 25 m]. Frey and Howard 1969:440, pl. 4, Figure 2, table 1 [Sapelo Island]. Dahlberg and Heard 1969:24 [Sapelo Island beach, Doboy Sound, Mud River, and Wassaw Sound, Georgia; from stomach of southern stingray]. Dörjes 1972:190 [Sapelo Island]. Hoese, 1973:79, 80 [off Sapelo Island, 9-12 fms (16-22 m) and Upper Duplin River (6 m)]. Camp 1973:39, Figure 14 [west coast of central Florida, depths 6 and 18 m]. Howard and Frey 1975a:12 [North and South Newport Rivers and adjacent parts of Sapelo and St. Catherine's Sounds, Georgia]; 1975b:55, Figure 3a [Georgia estuaries]. Gore and Becker, 1976: 154, 155, 156, 157, 158, 159, 168, Figure 9 [east coast of central Florida, depths 18 100 m]. Anderson et al. 1977:9 [Folly Beach, South Carolina, in surf zone]. Fox and Ruppert 1985:51, 69, 121, 137, 147, 195, 207, 258, 285 [sounds and
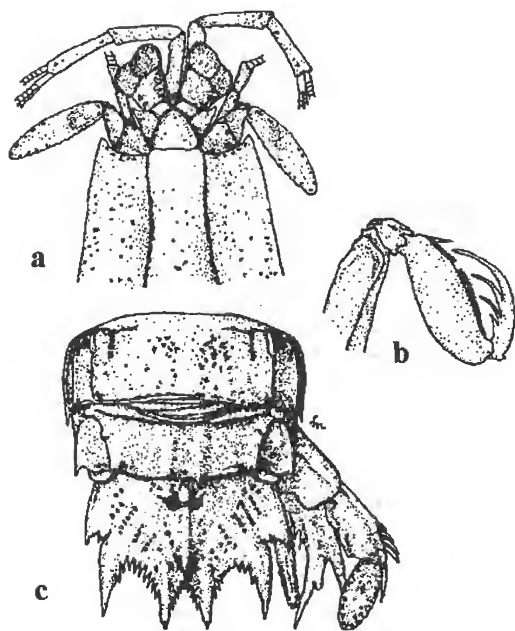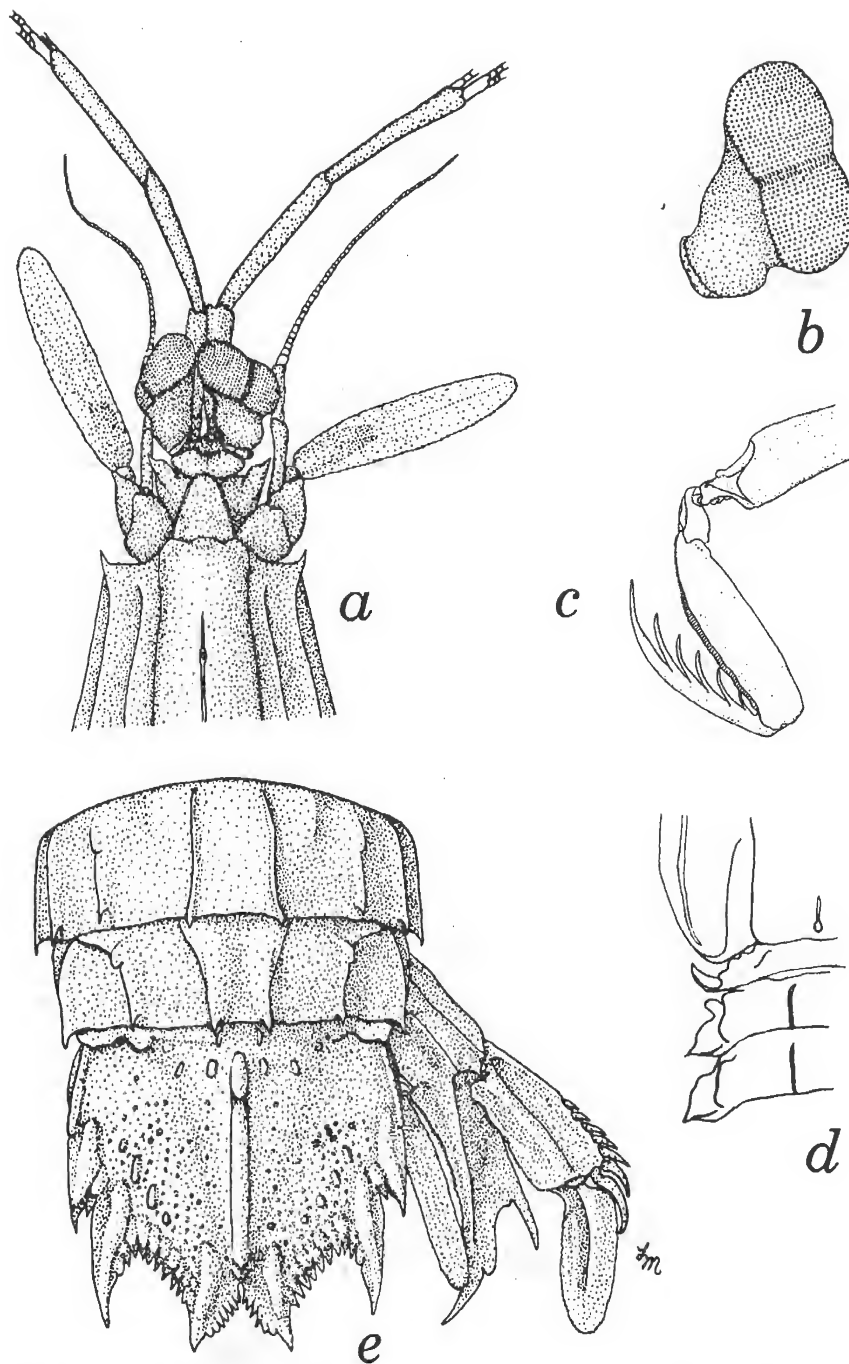
Figure 16. *Squilla deceptrix* Manning. a, anterior part of body; b, eye; c, raptorial claw; d, lateral processes of exposed thoracic somites; e, posterior two abdominal somites, telson, and uropod. (a,b,d,e, from Manning 1969:Figure 46a-c,e; c, ♂ holotype, tl 67 mm, off Panama, USNM 119169).
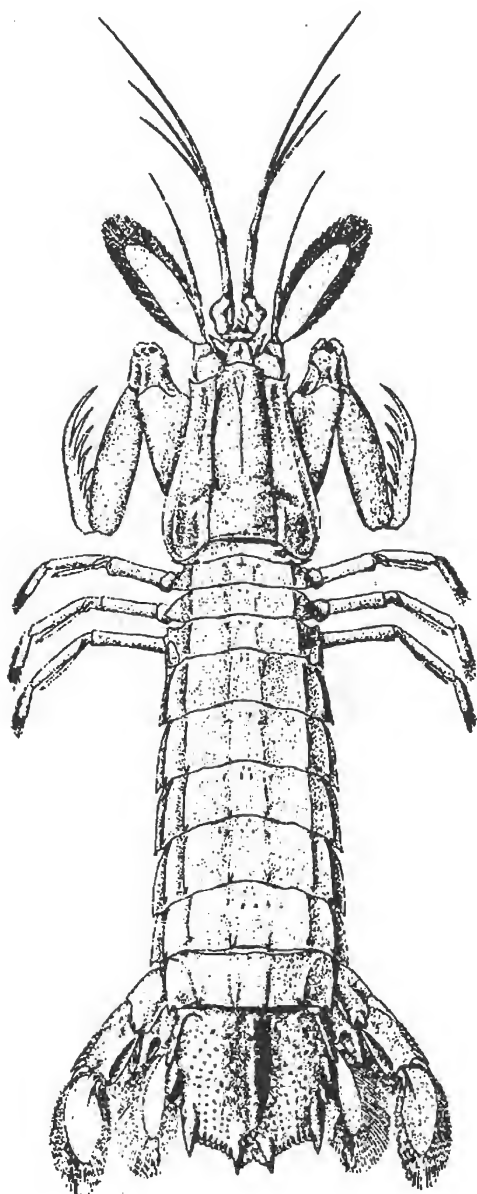
Figure 17. *Squilla empusa* Say. **Dorsal view (from Rathbun 1893: pl. 274).**

protected beaches along entire South Carolina coast]. Wenner and Wenner 1989:159, 160, 161, 164, 167, 172, Figure 4 [Cape Fear, North Carolina to Cape Canaveral, Florida, depth 4-20 m].

Chloridella empusa. Lunz 1935:157, Figure 6 [North and South Carolina].-Pearse et al. 1942:185 [Fort Macon and near Bird Shoal, Beaufort, North Carolina].

Chloridella. Pearse et al. 1942:146 [Bogue Bank, North Carolina, depths 3 and 15 m].

Squilla sp. Hertweck 1972:125, 126, 136, Figure 6a, pl. 1, Figure 14 [upper and upper part of lower offshore, Sapelo Island, Georgia, depths 1.6 to 12 m; burrow structure].

Material. North Carolina: 35°20'N, 75°20'48"W, 25 m, 17 Sep 1980: 1♀, 97 mm (USNM 189982). 34°59'N, 75°20'W, depth 35 fm (64 m), Combat sta 379, 17 Jun 1957: 1♂, 128 mm (USNM 170197). South Carolina: Hilton Head Island, leg. G. Ehnat: 1♂, 86 mm, 1♀, 112 mm (USNM 173112). Georgia:31°13'N, 81°13'W, 11 m, SABP, 31 Aug 1977: 1♂, 100 mm, 1♀, 117 mm (USNM 174479). Duplin River, leg. J. Kraeuter, Mar 1973: 1♂, 57 mm (UG). Savannah and Brunswick, 2-7 Apr 1973: 4♂♂, 50-70 mm (UG). Marsh Island, Sapelo, 27 Jul 1961: 1♀, 58 mm (UG).

Remarks. The specimen from Marsh Island was taken together with *G. neglecta*.

This species and *G. neglecta* were taken together at one station in Sapelo Sound, Georgia by Howard and Frey (1975a), but more than 100 other specimens of *S. empusa* were taken by them at nine other stations in the North and South Newport Rivers and St. Catherines and Sapelo Island Sounds, in surface salinities ranging from 11.7-34.1‰. Apparently *S. empusa* is common locally in Georgia estuaries but not in deeper estuarine channels (Howard and Frey 1975b). Frey and Howard (1969:pl. 4, Figure 2) and Howard and Frey (1975b:Figure 3a) showed a cast of the burrow of *S. empusa*, which consists of several inter-connected sections; it is described by Frey and Howard (1969:440) as "irregular, branched or unbranched, broadly U-shaped burrows 2 to 4 cm in diameter and a meter or more in length."

Dahlberg and Heard (1969:25) reported that *S. empusa* was found in the stomach contents of a southern stingray, *Dasyatis americana* Hildebrand and Schroeder taken in Wassaw Sound, Georgia. Fox and Ruppert (1985) considered this species to be common all year along the South Carolina coast. In the waters ajacent to Sapelo Island, Ga., Hoese (1973:75) reported that "Mantis shrimp [*Squilla empusa*] were most common offshore [central Georgia inshore continental shelf] in 9-12 fms. However, none were found there in the summer months (May-August). In the bay [Doboy Sound] large numbers were taken at night in October, February and April. In August, however, few were taken during the day or night, and there was no marked nocturnal abundance.

The summer absence is not explained but may be related to spawning, because larvae and young were found only during the summer. This species constructs a crawfish-like burrow, where it apparently remains by day. Only two were taken in the upper Duplin [tidal tributary of Doboy Sound]."

Hertweck (1972) described the burrow structure of a species of *Squilla*. The burrows were found offshore in depths of 1.6 to 12 m in fine sand with silt or medium sand. They most likely are the burrows of *S. empusa*.

Wenner and Wenner (1989) reported that this species ranked second to *Portunus gibbesii* Stimpson in total catch and that it occurred in 78% of the trawl tows made in their study area, the Carolinean shelf between Cape Fear, North Carolina and Cape Canaveral, Florida, in depths between four and 20 m. In biomass, *S. empusa* constituted 11% of the total catch and was outranked only by the blue crab, *Callinectes sapidus* Rathbun.

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Spatial and Temporal Changes in Subtidal Benthic Crustaceans Along a Coastal River-Estuarine Gradient in Mississippi

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SPATIAL AND TEMPORAL CHANGES IN SUBTIDAL BENTHIC CRUSTACEANS ALONG A COASTAL RIVER-ESTUARINE GRADIENT IN MISSISSIPPI

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ABSTRACT Benthic crustaceans were collected monthly between 24 August 1985 and 20 September 1986 from tidal freshwater (TFW), oligohaline (OH) and mesohaline (MH) sites in Old Fort Bayou, a black-water tidal river of the Biloxi Bay estuary, Mississippi. Salinity varied seasonally and spatially and was primarily related to variations in rainfall during this study. Reduced rainfall after October 1985 resulted in the upstream movement of saline water and a concommitant shift in benthic crustaceans upstream with this change in the physical-chemical environment. This shift is supported by a significant positive concordance of ranks between salinity and relative abundance of *Gammarus sp. A* (Kendall's tau-c = 0.458 and Spearman's r_s = 0.704, p<0.007) and *G. mucromatus* (Kendall's tau-c = 0.497 and Spearman's r_s = 0.701, p <0.007) at TFW indicating that when salinity became high, so did the relative abundance of these two species in TFW. No specimens of either species were collected at this site during the same months in 1985. There was no relationship between salinity and relative abundance of *G. bonnieroides* (Kendall's tau-c = 0.201 and Spearman's r_s = 0.381, p = 199) in the TFW site. At the OH site, there was a marginally significant concordance (Kendall's tau-c = 0.432 and Spearman's r_s = 0.545, p = .053) between salinity and relative abundance of *G. bonnieroides* but not for the other two species. Riverine estuarines are by nature dynamic in their physical-chemical environment. Such variation influences macrobenthic distribution which has important trophic implications because these organisms form a large portion of the food base for higher trophic levels, such as fishes.

INTRODUCTION

Numerous studies have examined spatial and temporal patterns of benthos in estuarine shallow-water habitats in the northern Gulf of Mexico (Harrel et al. 1976; McBee and Brehm 1982; Gaston et al. 1988; Gaston and Nasci 1988; LaSalle and Rozas 1991; Gaston et al. 1995). Direct examination of changes in composition or density with seasonal environmental changes (Chapman and Brinkhurst 1981; Flint and Kalke 1985; Holland et al. 1987) are common but the effect of catastrophic changes in environmental conditions has not been extensively examined in estuarine systems (Hoese 1960). This study documents the spatial and temporal dynamics of benthic crustaceans from three subtidal sites along Old Fort Bayou, Mississippi as physical-chemical factors changed during a drought, and discuss the influence of variable benthic prey availability on foraging of fish predators.

MATERIALS AND METHODS

Macroinvertebrates were collected monthly, except for October 1985, between 24 August 1985 and 20 September 1986 from tidal freshwater (TFW), oligohaline (OH) and mesohaline (MH) sites (Cowardin et al. 1979) in Old Fort Bayou, a black-water tidal river of the Biloxi Bay estuary, Mississippi. The distance

between TFW and OH sites was about 4 km whereas the distance between OH and MH was about 13 km. A detailed description of each site was given by Peterson and Ross (1991). Ten cores were taken haphazardly to a depth of 10 cm within each site with a 5.5 cm I.D. PVC corer (23.8 cm^2; Lewis and Stoner 1981) and were spaced about 2 meters apart. Dauer et al. (1987) indicated that > 94% of all individuals and species occurred in Cheaspeake Bay within this depth. Since the sampling area within the TFW and OH sites was determined visually to be 70% vegetated *Myriophyllum aquaticum* (Vell.) Verde. (parrot-feather), *Elodea canadensis* Michx. (waterweed), *Vallisneria americana* Michx. (wild celery), *Eleocharis* spp (spike-rush), *Juncus* spp. (rush), *Crinum americanum* L. (southern swamp lily), *Pontederia cordata* L. (pickerelweed), and *Sagittaria lancifolia* L. (lance-leaved arrowhead)) and 30% non-vegetated (Peterson and Ross 1991), I used a stratified sampling design to estimate macroinvertebrate densities (*sensu* Krebs 1989). The number of cores within the vegetated strata were 7 whereas 3 cores were used in the non-vegetated strata. No submerged vegetation was present at the MH site and all cores were taken subtidally. Samples were washed in the field on a 0.5 mm sieve, the material collected was preserved in 10% buffered formalin and stored in 45% isopropyl alcohol. Crustaceans were identified to species and presented as a total number per site and date. Prior to each collection,

salinity was recorded from a littoral area of each site. Salinity were measured with a YSI Model 33 S-C-T meter. Rainfall for Biloxi, Mississippi was obtained from NOAA Climatological Data (Ashville, N.C.) between June 1951 and September 1985 and was used to construct mean $\pm$ 95% confidence intervals (CI) for this 17 year period of time. These data were used to compare to rainfall during this study.

I used the nonparametric Kendall's tau-c and Spearman's rank correlation statistic (Siegel 1956) to compare salinity within each site over the 13 months and the corresponding abundance of the more abundant crustaceans. Positive values based on ranks are considered concordant; thus high (or low) species abundance was associated with high (or low) salinity within a site. Alternatively, negative values based on ranks are discordant, indicating one variable increases while the other decreases. Ranks were considered significantly concordant or discordant if $p < 0.05$.

RESULTS

During the 13 months of this study the sites received excess rainfall from three hurricanes between August-October 1985, and markedly reduced rainfall during the remainder of the period. Rainfall in the area was markedly above and below the 17 year mean ($\pm$ 95% confidence intervals; Figure 1). Salinity varied seasonally and spatially and was primarily related to variations in rainfall during this study (Figure 1). Reduced rainfall after October 1985 resulted in the upstream movement of saline water. By April 1986, salinity at the TFW site (4‰) was categorized as oligohaline (0.5-5.0‰), the OH site (10.0‰) was mesohaline (5.0-18.0‰), and the MH site (18.5‰) approached polyhaline salinities (18-30‰) (Figure 1).

Overall taxonomic composition varied among sites (Table 1) with non-amphipod abundance being low relative to the amphipods. The TFW site was dominated by *Grandidierella bonnieroides* and *Gammarus sp. A* (near *G. tigrinus*), the OH site by *G. bonnieroides* and *Gammarus* sp. (macromucronata form, Heard 1982), and the MH site was dominated by *Corophium louisianum* and *G. bonnieroides* (Table 1). Shifts of crustaceans occurred within the TFW and OH sites (Figure 2). *Gammarus sp. A*, *G. mucronatus* and *G. bonnieroides* shifted upstream (Figure 2) when salinity increased at TFW (Figure 1). This shift is supported by a significant positive concordance of ranks between salinity and relative abundance of *Gammarus sp. A* (Kendall's tau-c = 0.458 and Spearman's r_s = 0.704, p < 0.007) and *G.*

mucromatus (Kendall's tau-c = 0.497 and Spearman's r_s = 0.701, p < 0.007) (Table 2) at TFW, indicating that when salinity became high, so did the relative abundance of these two species in TFW. No specimens of either species were collected at this site during the same months in 1985 (Figure 2). There was no relationship between salinity and relative abundance of *G. bonnieroides* (Kendall's tau-c = 0.201 and Spearman's r_s = 0.381, p = .199) in the TFW site. This shift began in April 1986 in the OH site and June 1986 in the TFW site (Figure 1). At the OH site, there was a marginally significant concordance (Kendall's tau-c = 0.432 and Spearman's r_s = 0.545, p = .053) between salinity and relative abundance of *G. bonnieroides* but not for the other two species (Table 2).

DISCUSSION

Benthic crustaceans shifted upstream with seasonal changes in their physical-chemical environment in coastal Mississippi. Similar spatial and temporal macrobenthic distribution patterns also have been documented in other estuaries (McLusky 1968; Harrel *et al.* 1976; Chapman and Brinkhurst 1981; Dauer et al. 1987). Peak abundance of crustaceans occurred at different times of the year in Old Fort Bayou and was habitat specific. For example, in the MH habitat, peak abundance was between January and April and *C. louisianum* was the dominant species whereas in the OH habitat, peak abundance occurred between May and September and *G. bonnieroides* and *Gammarus* sp. "macromucronate form" were the dominant species. In the TFW habitat, peak abundance occurred between July and September and *G. bonnieroides* and to a lesser degree *Gammarus* sp. A were the dominant species. *Corophium louisianum* occurred in more saline habitats than less saline upstream habitats of Old Fort Bayou. This distribution pattern was similar in the Calcasieu estuary in Louisiana (Gaston and Nasci 1988), Neches River estuary in Texas (Harrel et al. 1976) and Wolf River estuary in Mississippi (Milligan 1979).

Abundance patterns of crustaceans may vary geographically in the northern Gulf of Mexico as well as spatially and temporally within a single system as noted in this study. For example, while *G. mucronatus* was most abundant during winter and spring in a salt marsh (0- ~29‰) in Florida (Subrahmanyam et al. 1976), in Old Fort Bayou it was abundant during summer and fall. *Corophium louisianum* peaked between March and July in a brackish marsh (0-10‰) in Mississippi, which coincides with a major reproductive period of this species
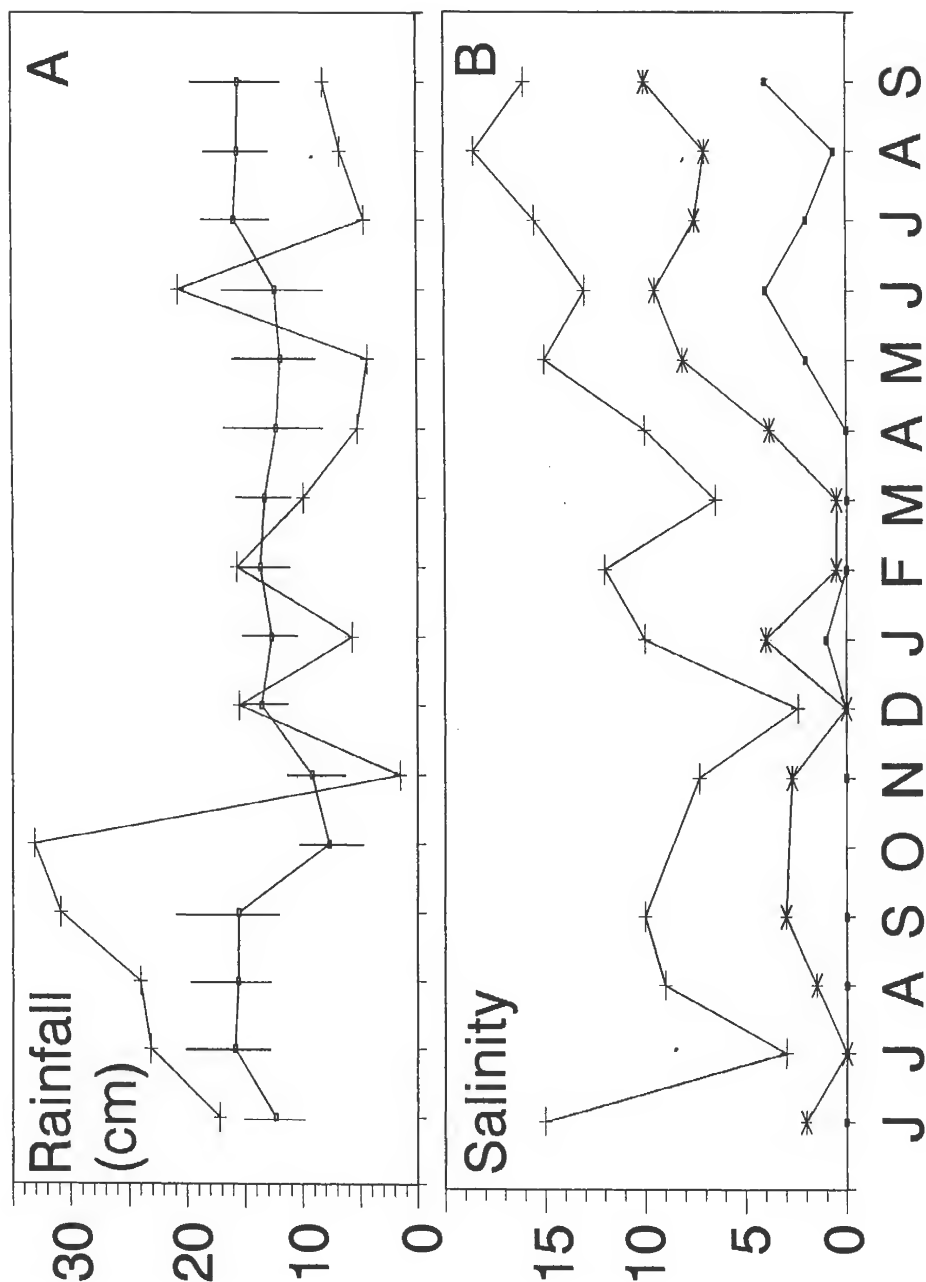
Figure 1. Rainfall data from Biloxi, Mississippi and monthly salinity data for all three sites. Rainfall between June 1951 and May 1985 (mean ± 95% CI) and rainfall during the course of this study (June 1985-September 1986) are plotted in panel A. Excessive rainfall from three tropical storms or hurricanes influenced these sites in August to October. Salinity is plotted in panel B. A square = TFW site, * = OH site, and + = MH site.

TABLE 1

Total numbers of tanaids, isopods and amphipods based on 10 cores of 23.8 cm² area pooled by month (n = 130 cores /site) at three sites in Old Fort Bayou, Mississippi. TFW = tidal freshwater, OH = oligohaline, MH = mesohaline.

Species	TFW	OH	MH
Tanaidacea			
Hargaria rapax	0	0	5
Isopoda			
Edotea triloba	0	4	4
Cyathura polita	0	10	0
Amphipoda			
Gammarus sp. A (near G. tigrinus)	27	4	0
G. mucronatus	15	2	1
G. sp. "macromucronate form"	2	38	0
Corophium louisianum	0	2	791
Grandidierella bonnieroides	191	140	30
Hyalella azteca	1	1	0
Melita sp.	1	6	0
Total # individuals	237	207	831
Total # species	6	9	5
Peak abundance	July-Sept	May-Sept	Jan-April

(LaSalle and Rozas 1991) but was abundant in Old Fort Bayou only during January to April at the MH site.

Riverine estuaries are by nature dynamic in their physical-chemical environment. Such variation influences macrobenthic distribution which has important trophic implications because these organisms form a large portion of the food base for higher trophic levels, such as fishes.

Darnell (1962) noted that in Lake Pontchartrain, Louisiana "the community probably never really becomes stabilized before a new set of equilibrium conditions is established and the process begins over again". In Texas, Harrel et al. (1976) indicated that "riverine estuaries are seasonally programmed and very dynamic; thus water quality and the biota constantly change."

Spatial and temporal species responses may be functionally important to fishes that use various parts of the estuarine gradient during their life-history. Nelson et al. (1982) discussed the importance of amphipods as major prey items of fishes in seagrass meadows in Florida and noted spatial and temporal variability of amphipods within a single lagoon system. Since differences in species composition and density of prey have been shown to be key factors in growth of fishes (Adams et al. 1982; Barwick and Lorenzen 1984), changes

in either factor may play a role in foraging patterns of fishes that feed on benthic macroinvertebrates. For example, estuarine-dependent fishes that "pulse" up the estuary during winter and spring (i.e., *Leiostomus xanthurus*, spot and *Micropogonias undulatus*, Atlantic croaker) of dry, low-rainfall years may encounter a different suite of macrobenthic prey than those that move upriver in wet, high-rainfall years. This phenomenon would also effect freshwater fishes (i.e., *Lepomis* spp. and *Micropterus* spp.; Peterson and Ross 1991) that also use the low-salinity part of the estuary and are trophically opportunistic (Desselle et al. 1978).
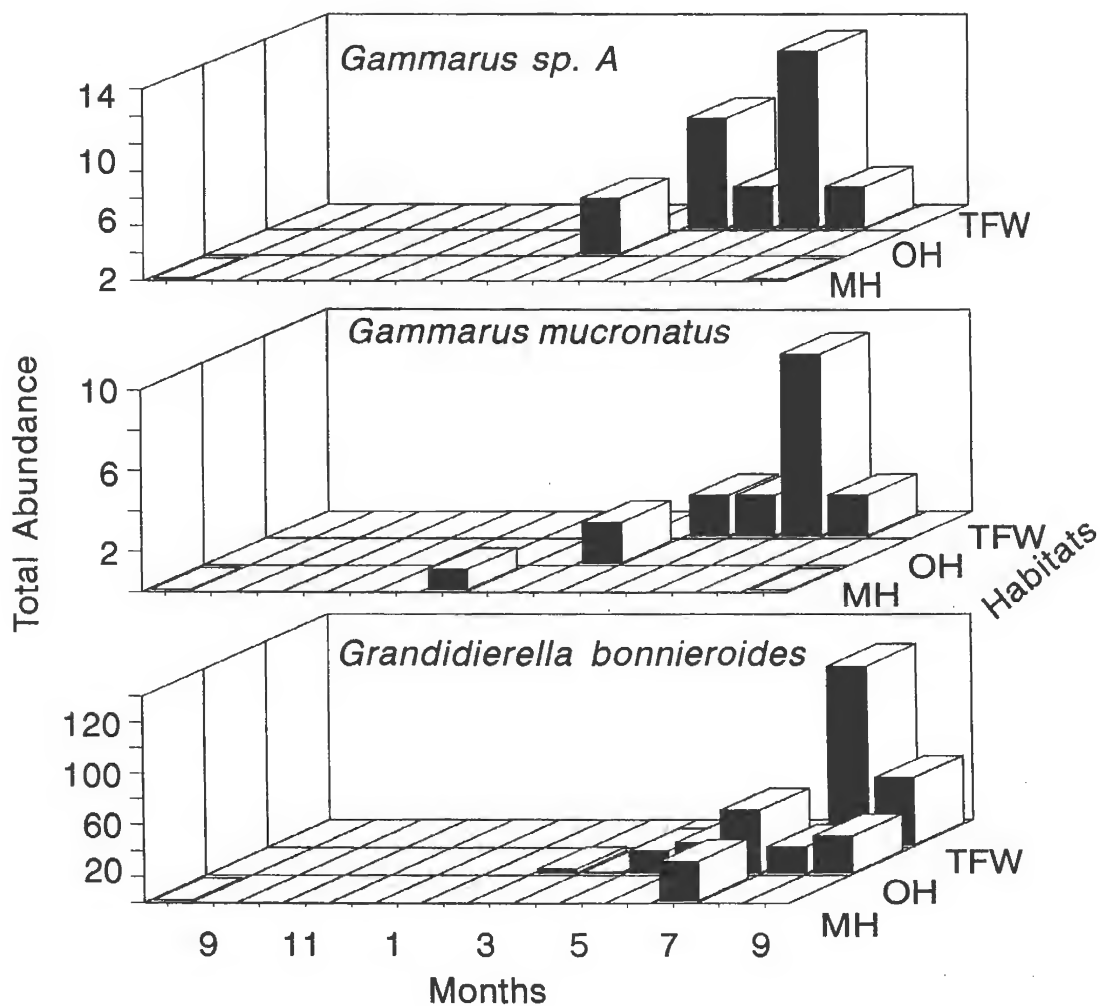
Figure 2. Plot of the total abundance and habitat distribution of *Gammarus sp. A* (near *G. tigrinus*), *Gammarus* sp. (macromucronatus form), and *G. mucronatus* from the tidal freshwater (TFW), oligohaline (OH) and mesohaline (MH) sites in Old Fort Bayou, Mississippi.

TABLE 2

Results of the Kendall's tau-c and Spearman's correlation statistics. Values presented are the p-values for the tests comparing ranks of salinity and relative abundance of each species by site. TFW = tidal freshwater, OH = oligohaline, MH = mesohaline. An * indicates insufficient number of specimens to run the analysis.

Species	TFW	OH	MH
Gammarus sp. A (near *G. tigrinus*)	.007	*	*
Gammarus mucronatus	.007	*	*
Grandidierella bonnieroides	.199	.053	*

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Gulf Research Reports

Distributional and Ecological Notes on the Halfbeaks of Eastern Gulf of Mexico, with a Provisional Key for Their Identification

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DISTRIBUTIONAL AND ECOLOGICAL NOTES ON THE HALFBEAKS OF EASTERN GULF OF MEXICO, WITH A PROVISIONAL KEY FOR THEIR IDENTIFICATION.

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ABSTRACT Several fishes of the halfbeak genus *Hyporhamphus* occurring in the Mexican Gulf of Mexico and Caribbean Sea have been misidentified or confused in the literature. Most of it has centered around the taxonomic status of *H. unifasciatus* (including its synonym *H. roberti*), which is shown to comprise a complex of three species, *H. unifasciatus*, the recently described *H. meeki*, from the western Atlantic region, and an undescribed species from the eastern Pacific Ocean. Another eastern Mexico halfbeak is the freshwater form *H. mexicanus*. Using Banford and Collette (1993), we examined specimens from collections at UANL, UNAM, IPN, and ECOCH and have clarified the Mexican distribution of these species. We here report additional Mexican records of *H. meeki*, previously known only from United States waters and from the coast of Yucatán, clarify the distribution of *H. unifasciatus*, and provide the first marine record of the freshwater species *H. mexicanus*. A distribution map and keys for identification of the eastern Mexican species are provided.
KEY WORDS: hemiramphines, halfbeaks, México, fish distribution, fish ecology.

INTRODUCTION

The recent description of the new hemiramphine fish species *Hyporhamphus meeki* Banford and Collette (1993), mostly from northern Gulf of Mexico and western north Atlantic, makes it necesary to correct the records of the eastern Mexican members of the *Hyporhamphus* complex. Banford and Collette (1993), when describing their new species had examined 60 specimens in seven lots from only four localities in Mexican waters. Published records from the Mexican Gulf coast have been relatively few, compared to the well sampled Atlantic and Caribbean areas. Banford and Collette (1993) gave the distribution of the new *H. meeki* as Passamaquody Bay to Florida, Galveston (Texas), and Yucatán. They constrained the name *H. unifasciatus* (and its synonym *H. roberti*), to the northern form ranging from Florida, then south to the southern Gulf of Mexico, West Indies and Uruguay. One species, *H. mexicanus*, was formerly known only from freshwaters of Río Coatzacoalcos and Río Usumacinta. Records of *H. unifasciatus* from the oriental Pacific Ocean were regarded as an undescribed species of the genus (Banford and Collette 1993). Re-identification of such records should await the description of the new species and a future paper shall analyze their Mexican distribution.

The records from Tamaulipas (Gómez-Soto and Contreras-Balderas 1988) are a composite of *H. unifasciatus* and *H. meeki*, based upon re-examination of specimens at UANL. *H. unifasciatus* and *H. roberti*,

were recorded from the coasts of Veracruz (Castro-Aguirre 1976; Reséndez 1979; 1981, 1991; Reséndez and Kobelkowski 1983; Lozano-V. García-R. and Contreras-B. 1993), and often included in their samples also *H. meeki*. Some of the specimens of said authors were re-identified, as shown in the synonymy and materials sections, under each species. Other records cannot be assigned to either species, unless they can be related to specific samples in the catalog of UNAM, such as *H. unifasciatus* from Pueblo Viejo, La Mancha, Mandinga and Términos (Reséndez, 1991; Reséndez and Kobelkowski 1983); and *H. roberti* from Tamiahua, Mandinga, and Alvarado (Reséndez 1991; Reséndez and Kobelkowski 1983).

MATERIALS AND METHODS

Fish Collections referred to in this paper were those housed at Universidad Autónoma de Nuevo Leon (Facultad de Ciencias Biológicas, Monterrey) as UANL, Universidad Nacional Autónoma de Mexico-Instituto de Biologia (basis of some published records) as UNAM-P, Instituto Politecnico Nacional/Escuela Nacional de Ciencias Biologicas as IPN(ENCB-P), both from Mexico City, and Colegio de la Frontera Sur/Unidad Chetumal, Quintana Roo, are referred to by their acronyms, recognized as official (Leviton et al. 1985; Leviton and Gibbs 1988), except the last one, for which the institution uses ECO-CH (J. Schmitter 1996: pers. com.). Methods used were the standard methods of Hubbs and Lagler

(1947), as reported diagnostic for the species by Banford and Collette (1993), such as total gill rakers on first and second arches, pectoral rays, and ratio of preorbital length to orbit diameter; scales in lateral series and anal rays, are used in the taxonomic comments and in constructing the accompanying identification keys. Meristic ranges are presented as total (usual counts in parenthesis). A reliable field character is the width of longitudinal streak, as related to the orbit diameter. The distribution records appear on Figure 1.

MATERIAL EXAMINED

Species Accounts.
Hyporhamphus unifasciatus (Ranzani 1842).
H. roberti, Lozano-V., Garcia-R. and Contreras-B. 1993 (distr.). *H. unifasciatus*, Gomez-Soto and Contreras-B. 1988 (distr.); Lozano-V., Garcia-R., and Contreras-B., 1993 (distr.); Banford and Collette 1993 (descr., distr., comp.).

Specimens examined. Tamaulipas: UANL 7880 (2: 155-163 mm SL) and UANL 7897 (1: 149 mm SL), both Isla Vaca, Laguna Madre. Veracruz:UNAM-P 278 (5: 138-167 mm SL), Estero Cucharas and Ensenada Tigre in Laguna Tamiahua. UANL 10986 (1:162 mm SL), Mocambo Beach. UNAM 5410 (1:173 mm SL), Sontecomapan. UNAM-P 5324 (2:123-143 mm SL), Monte Pío, Los Tuxtlas. Campeche: UNAM-P 4620 (1: 143 mm SL), Muelle Los Piratas, Ciudad Campeche. Yucatan: UNAM-P 3189 (3:124-148 mm SL), Playa Margaritas, Celestún. UNAM-P 3161 (4:181-202 mm SL), Celestun.

Recognition. *H. unifasciatus* is recognized by the following combination of characters: dorsal and anal fins covered with scales; low gill raker count on first arch 26-35 (28-32), on second arch 19-28 (21-26); pectoral rays usually 9-12 (10-11); anal rays 14-18 (15-17); shorter lower jaw 150-310, ratio of preorbital length to orbit diameter <0.70. The longitudinal streak widens gradually towards the tail from pupil to eye diameter.

Ecological notes. Euryhaline species. Localities from Tamaulipas, Veracruz and Yucatan, are coastal lagoons or estuaries, except Mocambo, and all have relatively turbid waters. The locality from Campeche is open and sandy, with strong influence of submerged phreatic freshwater springs, usual around the Yucatán Peninsulae, hence equivalent to brackish water.

Distribution. This is a southern species, ranging south from Laguna Madre (Tamaulipas México), around the Gulf of México to eastern and southwestern Florida Peninsula, through the Caribbean Sea, south to Rio de la Plata, Uruguay. Figure 1 shows only records from Mexican institutions.

Size. Maximum 205 mm SL.

Hyporhamphus meeki Banford and Collette 1993.
Hemirhamphus unifasciatus, Reséndez, 1981:267-268 (Laguna Panlau, Camp., char.). *Hyporhamphus meeki* Banford and Collette' 1993 (orig. descr., distr. comp.)

Specimens examined. Tamaulipas: Laguna Madre at Carbonera. UANL 7701 (10:138-164), same locality. UANL 7724 (2:38-43). UANL 10429 (1:148), same locality. UANL 10393 (2:40-63), same locality. UANL 7670 (2:149-152), Laguna Madre at Boca de Catán. UANL 11898 (3:38-76), Laguna Madre at Mezquital. UANL 7478 (1:156), Mouth, Río Soto La Marina. Veracruz: UNAM P 7308 (5:138-167), Ensenada Cucharas and Ensenada El Tigre. UNAM P 2420 (2:147-154), Juan Román, Laguna de Tamiahua. UNAM P 2425 (1:144), Canal de Isla, Tamiahua. UNAM P 2718 (1:129), El Higuerón, Laguna de Tamiahua. UANL 788 (1, 177), Isla Lobos. UANL 10961 (1, 186), Casitas. UNAM P 529 (1:216), Between Tauche and El Real, Sontecomapan. IPN/ENCB P 2478 (1:232), Barra de Sontecomapan (N de la laguna). Yucatán: UNAM P 7708 (1:125), Playa Margaritas, Celestún. UNAM P 798 (1:154), Puerto Progreso. Quintana Roo: ECO-CH 3086 (1:145), Playa El Arenal, Laguna de Bacalar.

Literature records. Reséndez (1981) reported as *H. unifasciatus* a specimen from Laguna Panlau (Campeche) as having 37 gill rakers on the first arch, which is well within the range of *H. meeki*. Banford and Collette (1993) listed and maped (slightly misplaced to the west) two Mexican records, Progreso and the nearby Chixchulub, Yucatán. Other literature records, are unidentifiable, and probably a mixture of species.

Recognition. *H. meeki* is easily recognized by having the dorsal and anal fins covered with scales; total gill rakers on first arch, 31-43 (32-39); pectoral rays usually 10-13 (11-12); anal rays 14-18 (15-17); longer lower jaw 206-351; ratio of preorbital length to orbit diameter >0.70. The longitudinal streak is as wide as pupil and widens abruptly to twice its width just before and below dorsal fin.

Ecological notes. The coralline Isla de Lobos is the only Mexican record of *H. meeki* from strictly marine and reef waters; the Yucatan Peninsula records are from areas with freshwater influence, as explained above; all other collections are from coastal lagoons or estuaries, with usually turbid waters.

Distribution. *H. meeki* is mostly northern in distribution, occurrying through the Gulf of México
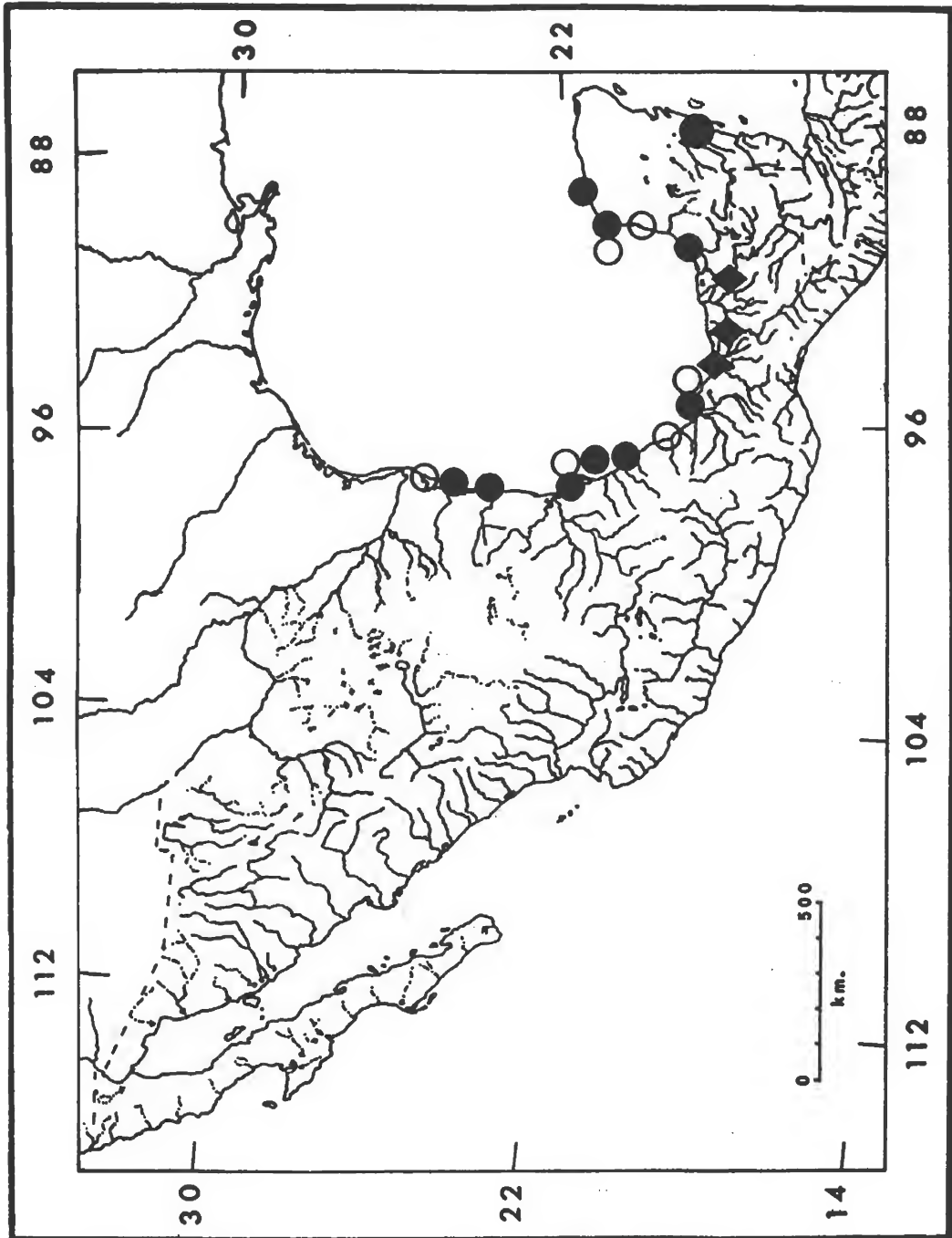
Figure 1. Distributions of eastern México Hemiramphine fishes of the genus *Hyporhamphus* based on Mexican collections only:

●   *H. meeki*   0   *H. unifasciatus*   ◆   *H. mexicanus*

Paired symbols indicate sympatry.

(most Mexican states, not yet recorded from Tabasco, México), around Florida, and north to Camcook, Passamaquody Bay, New Brunswick, Carolina. Here recorded for the first time from the Caribbean region at Laguna Bacalar, Quintana Roo, México. Figure 1 shows only records from Mexican institutions.

Remarks. Gill raker count is increased to a maximum of 43 (UANL 7724, Laguna Madre at Boca de Catán).

Size. Maximum 232 mm SL (IPN P-2478, Barra de Sontecomapan, north of the lagoon).

Hyporhamphus mexicanus Alvarez 1959.
Hyporhamphus mexicanus Alvarez 1959 (orig. descr., comp.), Río Coatzacoalcos, Santa María Chimalapa, Chiapas. Miller 1966 and 1976 (distr.) Lozano-Vilano and Contreras-Balderas 1987 (list.)

Specimens examined. Veracruz: UANL 2416 (1: 188); pool 1 km E from mouth of Río Coatzacoalcos (marine beach). Tabasco: UANL 2339 (1:55); San Fernando, Río Usumacinta. Chiapas: UANL 5804 (7: 52-87); Lago Catazajá, Río Usumacinta.

Recognition. Dorsal and anal fin interradial membranes without scales; total gill rakers on first arch 19-20; pectoral rays 10-11; anal rays 12-14; scales in lateral series 52-59.

Ecological notes. This species, all previous records of which are from freshwater, is here recorded from probably marine water (very salty to taste, salinity not measured), based on capture of a single specimen from a beachside pool, just below the high tide mark, on the Gulf coast 1 Km E of the mouth of Río Coatzacoalcos. No source of freshwater (creek or bayou) was in the immediate vicinity. This halfbeak might be incidentally collected in marine waters of this region, near river mouths. The catch included nine euryhaline species and one barracuda.

Distribution. Ríos Coatzacoalcos and Usumacinta, and neighboring Gulf of México. Figure 1 shows records from Mexican collections only.

Size. This is a small species, maximum SL 118 mm.

DISCUSSION

The presence of two halfbeak species in the genus *Hyporhamphus* in coastal waters of México has not been recognized until recently (Banford and Collette 1993) and three in this paper. *H. meeki* and *H. unifasciatus* are euryhaline and roughly sympatric in the Gulf of México. They occur in the same lagoon, as evidenced by records at Laguna Madre, Tamaulipas, Laguna Tamiahua and Laguna Sontecomapan, Veracruz. They have also been taken together at Indian River Lagoon, Florida (Banford and

Collette 1993), and two Mexican localities: Ensenada Cucharas and Ensenada Tigre (Laguna Tamiahua, Veracruz), and Playa Margaritas, Celestún (Yucatán). Some specimens cited in published records were reidentified either as *H. unifasciatus* or *H. meeki*. Most literature records for the Gulf of Mexico, under the synonym names *H. unifasciatus* or *H. roberti*, may probably comprise that species and *H. meeki*, but can not be evaluated since they are not represented by published museum accesions. *H. mexicanus* hitherto known only from fresh water, is recorded for the first time from a marine tide pool locality and a few new inland localities.

Key To Eastern Mexican Hemiramphid Fish Species Of The Genus *Hyporhamphus*.

1a.- Dorsal and anal fin interradial membranes with numerous lines of scales.
  2a. Total gill rakers 26-35 (28-32); pectoral fin rays 9-12 (10-11); lateral band nearly even in width throughout its length, wider than pupil..........
  .... *H. unifasciatus.*
  2b. Total gill rakers 31-40, usually 32-37; pectoral rays 10-13 (11-12); lateral band as wide ad pupil on most of the body, doubling its width just before and below dorsal fin.......... *H. meeki.*
1b.- Dorsal and anal fin interradial membranes without scales. Total gill rakers 19-20; pectoral rays 10-11; lateral band similar to *H. unifasciatus*, being more slender; .... *H. mexicanus.*

RESUMEN

Varios peces hemirámfidos del género *Hyporhamphus* del Golfo de México y Mar Caribe mexicanos han sido mal identificados o confundidos en la literatura. La mayoria de estos casos está centrada alrededor de la situación taxonómica de *H. unifasciatus* (incluyendo su sinónimo *H. roberti*), que se sabe está compuesto por un complejo de tres especies, *H. unifasciatus*, el recientemente descrito *H. meeki* del Océano Atlántico occidental y una especie indescrita del Océano Pacífico oriental. Aplicando Banford y Collette (1993), re-examinamos ejemplares de las colecciones de UANL, UNAM, IPN, y ECOCH y hemos aclarado la distribución mexicana de estas especies. Aquí registramos localidades adicionales de *H. meeki*, anteriormente conocido sólo de Estados Unidos y de las costas de Yucatán, aclaramos la distribución de *H. unifasciatus*. Otra especie de mediopico del México oriental es la forma de agua dulce *H. mexicanus*, para la cual aportamos su primer registro marino. Se presenta un mapa distribucional y una clave de identificación de las especies estudiadas.

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Butyltins in *Crassostrea virginica* from Nine Reefs in Mississippi Sound

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BUTYLTINS IN *CRASSOSTREA VIRGINICA* FROM NINE REEFS IN MISSISSIPPI SOUND

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ABSTRACT Tributyltin (TBT), a very effective anti-foulant, has been banned from most marine paint uses since 1988 because of its reputed toxicity to nontarget organisms. *Crassostrea virginica* were collected from nine reefs in the Mississippi Sound in 1993 and analyzed for concentrations of butyltins: TBT, dibutyltin (DBT) and monobutyltin (MBT). TBT concentrations ranged from <2 to >20 ng(Sn)/g wet wt. Highest concentrations of butyltins were found at eastern Sound reefs near intense shipping and ship building activities with lowest concentrations found in the western Sound.

INTRODUCTION

Tributyltin (TBT) became widely recognized as an extremely effective anti-foulant in marine paints in the early 1980's. This application followed the use of other organotins as pesticides, disinfectants, and cotton, wood, and stone preservatives. The effectiveness of TBT in preventing attachment of fouling organisms to marine craft has been offset by its toxicity to nontarget organisms. Several excellent reviews highlight possible adverse effects from the butyltins (Heard et al 1989; Tas 1993; and Fent 1996). Publicity arising from various scientific studies led to a ban on use of TBT for most marine applications by the U.S. Organotin Anti-Fouling Paint Act of 1988. The National Status and Trends Program (NS&T) of the National Oceanic and Atmospheric Administration was created to assess spatial distributions and temporal trends in chemical contaminants in all major U.S. coastal estuaries. In 1989 NS&T added butyltins [including dibutyltin (DBT) and monobutyltin (MBT), successive degradation products of TBT] as a parameter to be measured in oysters and mussels to determine whether the ban would effectively reduce levels of these compounds in sessile organisms exposed to butyltins near regions of intense boating activity.

Three oyster reefs in Mississippi Sound were chosen as sites for NS&T studies and results are available for 1989-1993 collections in a report by O'Connor and Beliaeff (1995). The purpose of this study was to thoroughly investigate TBT residue distributions in the oyster, *Crassostrea virginica*, from nine oyster reefs in the Mississippi Sound. Results of this study indicated that TBT levels were similar to those found at the three sites reported by NS&T for 1989-1993.

METHODS

Oysters were collected at nine reefs in the Mississippi Sound, with locations shown in Figure 1, placed on ice and taken to the analytical chemistry laboratory at the Gulf Coast Research Laboratory on the day of collection. Oysters were collected from Gorenflo, White House, Pass Marina and Front Pass Harbor Reefs on November 4, 1993; from Graveline, East River, West River, Bang's Lake and Middle River Reefs on November 9, 1993.

Analysis of fish tissue followed that of Durell and Uhler (1989) with the following brief details. Three samples from each reef were prepared by homogenizing three oyster tissues per sample. Samples were spiked with tri-*n*-propyltin as internal standard, dried over anyhydrous Na_2SO_4 and after acidification were extracted with a tissue homogenizer three times with tropolone in hexane. Butyltins were converted to pentyl derivatives and cleaned up with florisil chromatography. Samples were analyzed on a Perkin Elmer model 8500 gas chromatograph equipped with splitless injector and fitted with a 30m x 0.24mm (id) fused silica capillary column, 0.25μ film thickness DB-5 (J&W Scientific) and flame photometric detector modified for tin analysis by substitution with a photocell optimized for the 610nm wavelength which was selected by a photometric filter (Ditric Optics). The instrument was operated with He carrier gas set at 30cm/sec linear flow rate, helium make-up gas at 28.6ml/min, and hydrogen and air each set at 100ml/min. Programming temperatures were 75°, hold for 1min., programming to 150° @ 30°/min then to 210° @ 10°/min with 3 min. final hold. Detector and injector were each held at 250°C.

Identification of butyltins was made through retention time comparisons with authentic standards of all four butyltins pentylated in the laboratory. Likewise,
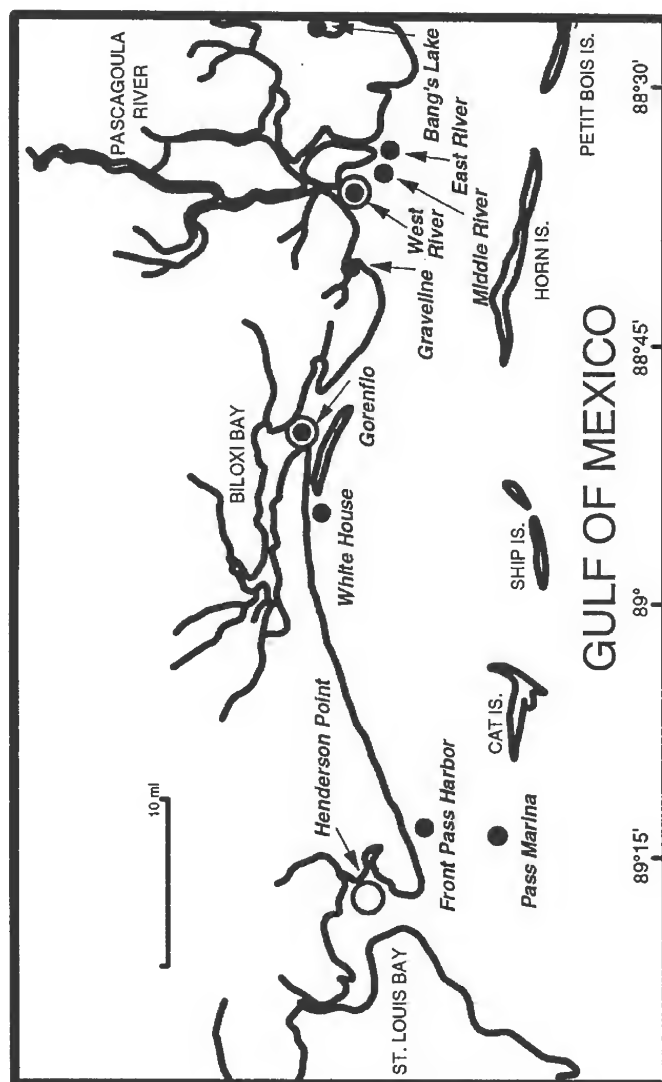
Figure 1. Oyster reefs in Mississippi Sound. Reefs sampled in present study are shown in solid circles; those sampled in NS&T study are in open circles with two sites sampled in both studies.

quantitative measurements were achieved through the use of the internal standard tri-*n*-propyltin and response factors generated through the use of the four butyltin standards. In a separate analytical validation procedure four-12 g aliquots of an oyster homogenate were analyzed before and after spiking with 50 ng(Sn)/g of the four butyltins and tri-*n*-propyltin. Quantitation in this analysis was effected by comparison to a second internal standard, dipentyldipropyltin, added just prior to gas chromatography. Absolute % recoveries of the five organotins were as follows: tri-*n*-propyltin, 64.5±8.3 (standard deviation); tetrabutyltin, 32.3±3.0; TBT, 77.2±5.1; DBT, 101±6.6; MBT, 90.6±4.6. No corrections are made in any reported values for % recoveries. All analyses were conducted under Good Laboratory Practices as described by U.S. Environmental Protection Agency (1983).

RESULTS

Butyltin concentrations for each of three oyster samples from each reef are given in Table 1. Though some values, notably for DBT, are above instrument detection limits, they are slightly below method detection limits and are included for purposes of reef intercomparisons and comparisons to literature from NS&T studies. Only TBT and DBT were detected in oysters from this study, whereas the NS&T study reported measurable levels of TBT, DBT and MBT. O'Connor (1992) proposed that a value of 53 ng(Sn)/g wet wt. be considered a "high" environmental level for total butyltins. This value was based upon results of oyster samples from 214 sites around the United States coastline in 1990 and reported by O'Connor and Beliaeff (1995)[1,2]. Only one sample from Middle River Reef had a value exceeding 53 ng(Sn)/g, and none of the samples from the other eight reefs had a value this high.

O'Connor and Beliaeff (1995) report an observed decline of butyltins at most sites in the U.S. from 1989 to 1993. This decline is presumably due to the ban on TBT use in marine paints. The mean value for all samples collected in the NS&T 1993 study was 4.8 ng(Sn)/g wet wt.[2], so the "high" value for total butyltins designated in 1990 is probably too high for a benchmark comparison for 1993 data. The mean values for total butyltins in oysters from five Mississippi Sound reefs were higher than 4.8 ng(Sn)/g and lower for four reefs.

TABLE 1

Butyltins in *C. virginica* from nine reefs in Mississippi Sound. *= mean of wet weights of 3 individual oysters ± one standard deviation. TBT=tributyltin, DBT=dibutyltin. nd = not detectable; for comparison purposes values are reported for butyltins that yielded a detectable chromatographic peak (Note that for some samples these values are below the method detection limits of: tetrabutyltin (TTBT)<1.2, TBT<2.2, DBT<1.6, monobutyltin (MBT)< 2.3 ng(Sn)/g wet wt). † = values for individual samples are followed by mean ± one standard deviation (TTBT and MBT were not detected in any sample).

Reef Sample Site	Wts, g*	Butyltins, ng(Sn)/g	
		TBT	DBT
Graveline	15.3±4.7	2.9	nd
	14.3±4.8	4.5	nd
	13.8±4.5	3.8	nd
	mean:	3.7±0.78†	nd
East River	10.3±1.9	6.9	1.7
	10.8±2.1	5.9	1.9
	10.1±9.2	3.9	0.73
	mean:	5.5±1.5	1.5±0.64
West River	11.6±5.7	22	3.6
	12.5±1.2	23	3.4
	11.8±1.2	27	3.7
	mean:	24±2.5	3.6±0.14
Bang's Lake	10.8±6.3	29	9.2
	17.2±3.9	10	4.3
	14.4±1.1	25	4.5
	mean:	22±10	6.0 ±2.8
Middle River	13.3±6.0	2.9	1.1
	9.6±3.6	1.3	0.57
	8.6±3.6	62	16
	mean:	22±34	5.9±8.9
Gorenflo	12.9±1.6	9.3	1.6
	12.6±4.3	11	2.5
	13.6±1.7	8.8	1.5
	mean:	9.6±1.0	1.9±0.51
White House	21.7±7.5	2.1	0.32
	21.9±2.6	2.0	0.48
	18.6±5.1	2.6	0.39
	mean:	2.2±0.31	0.40±0.08
Pass Marina	21.0±6.5	1.6	nd
	18.2±4.6	1.3	nd
	15.5±2.5	1.7	nd
	mean:	1.5±0.19	nd
Front Pass Harbor	16.2±2.6	2.8	0.62
	11.2±2.9	4.0	0.67
	14.4±6.3	3.0	0.48
	mean:	3.2±0.66	0.59±0.10

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[1]   This value was the mean plus one standard deviation of the lognormal distribution of concentrations among sites.

[2]   All NS&T butyltin concentrations were reported originally on dry wt. basis and have been converted to wet wt. basis assuming 85% moisture in oysters.

Butyltin concentrations in oysters collected in Mississippi Sound by NS&T are given in Table 2. Butyltin concentrations in oysters from West River (eastern Sound) and Gorenflo Reef (central Sound) can be compared directly to oyster concentrations at the same sites in the present study. NS&T data at Henderson Point can be used indirectly to compare values of butyltins in oysters from western Sound sites reported in this study.

DISCUSSION

In this study all samples collected at West River and Bang's Lake Reefs contained levels of TBT that were four to five times that of East River and Graveline Reefs. The latter two reefs had values very near to the 1993 NS&T mean value of 4.8 ng(Sn)/g. Only one sample at Middle River had a value in excess of the 1993 NS&T mean, and it was also the highest butyltin measured in this study. We expected relatively high levels of TBT at reefs at East River and Middle River considering the proximity to long-term shipbuilding interests in the region of the Pascagoula River. The prevailing westerly river flow across the Mississippi Sound apparently has resulted in greater impact on the West River Reef than on the two reefs further east at the mouth of this river (see Figure 1). This pattern of pollutant transport to the west of river sources in the Sound has also been demonstrated for petroleum hydrocarbons (Lytle and Lytle 1985). The high TBT values at Bang's Lake were not surprising considering connection of this estuarine lake to a number of industrial drainage sites, whereas Graveline Reef oysters, exposed only to residential development, contained the lowest levels of butyltin in the eastern Sound.

The largest sample to sample variation was observed in oysters at Middle River Reef with both TBT and DBT varying over an order of magnitude among samples. The extent of this pollutant range at a single reef, though entirely unlike that observed at other reefs, is not without precedent and was observed in heavy metal content in oysters at a single reef collected by Lytle & Lytle (1990) in Mississippi Sound. T. Lytle has also noted a marked individual variability in ability of oysters to uptake TBT in chronic exposures, with a negative correlation of size to TBT level (unpublished information).

In general, oysters from reefs in the central Sound contained less butyltin residues than in the eastern Sound. Oysters from Gorenflo Reef contained approximately four times higher butyltin concentrations than at White House Reef suggesting that its location in Biloxi Bay, directly in the path of boating activity, may have exposed these oysters to higher levels of butyltins.

TABLE 2

Butyltins in *C. virginica* from National Status & Trends Program (NS&T) study. Data derived from a single analysis of a composite of 20 oysters. Data originally collected on dry weight basis converted to wet weight basis assuming 85% moisture. All data obtained from http://www-orca.nos.noaa.gov/projects/nsandt/nsandt.html on the Internet. nd=not detected; detection limits not specified but presumed similar to those reported in Table 1.

| | Year | Butyltins, ng(Sn)/g | | |
		TBT	DBT	MBT
West River	1989	40	3.7	0.75
	1990	21	nd	nd
	1991	29	3.2	nd
	1993	13	1.1	0.21
Gorenflo	1989	69	4.0	nd
	1990	19	nd	nd
	1991	39	4.3	1.3
	1992	16	1.6	0.76
	1993	32	2.7	0.35
Henderson Point	1989	7.8	nd	0.15
	1990	2.2	nd	nd
	1991	2.8	0.66	1.5
	1993	1.5	0.61	0.19

Front Pass Harbor Reef and Pass Marina Reefs, located in the western Sound, had very low levels of butyltin residues. However, Front Pass Harbor Reef oysters had twice the level of butyltin residues as oysters from further offshore at Pass Marina Reef.

As shown in Tables 1 and 2, both this study as well as the NS&T study have shown that butyltins are highest in the Eastern Sound and lowest in the western Sound. This trend mirrors the decline in commercial boating activities in the western Sound. Though our study found more butyltins in oysters at West River Reef and less at Gorenflo Reef than did the 1993 NS&T study, the year to year fluctuations at both sites are so great that we believe that both sets of data are consistent. The present study has shown that there can be large variations in butyltin levels within and among adjacent reefs.

ACKNOWLEDGMENTS

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Size and Weight Relationships for the Golden Crab, *Chaceon fenneri*, and the Red Crab, *Chaceon quinquedens*, from the Eastern Gulf of Mexico

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SIZE AND WEIGHT RELATIONSHIPS FOR THE GOLDEN CRAB, *CHACEON FENNERI*, AND THE RED CRAB, *CHACEON QUINQUEDENS*, FROM THE EASTERN GULF OF MEXICO

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ABSTRACT: Carapace length, carapace width, and weight relationships are discussed for the golden crab, *Chaceon fenneri*, and the red crab, *Chaceon quinquedens*, from the eastern Gulf of Mexico. Males of both species were significantly larger than females in comparisons of means of all measured parameters. Relationships between carapace length and carapace width, carapace length and weight, and carapace width and weight were similar between Atlantic and Gulf of Mexico populations for both species.

INTRODUCTION

Deep water crabs of the family Geryonidae are widely distributed throughout the world oceans. Crabs of the genus *Chaceon* (formerly *Geryon*) are fished for human consumption along both sides of the Atlantic Ocean, including the coastal areas of southwest Africa (Melville-Smith 1988), the eastern United States (Ganz and Herrmann 1975, Erdman and Blake 1988), and Bermuda (Luckhurst 1986). Two species of *Chaceon* have been reported from the Gulf of Mexico, the golden crab, *Chaceon fenneri*, and the red crab, *Chaceon quinquedens* (Lockhart et al. 1990). Red crabs are found throughout the deep waters of the U. S. Gulf of Mexico with reported abundance centered in the northcentral Gulf of Mexico east of the mouth of the Mississippi River (Lockhart et al. 1990, Waller et al. 1995). Although golden crabs have been reported from slope waters west of the Mississippi River (Waller et al. 1995), population densities are highest in the eastern Gulf of Mexico adjacent to peninsular Florida (Otwell et al. 1984, Lockhart et al. 1990).

The minimum size for harvest of red crabs in the Atlantic fishery has been set at a carapace width of 114 mm (Armstrong 1990). A minimum carapace width of 121 mm has been proposed for golden crabs in the southeast Atlantic Ocean by the South Atlantic Fishery Management Council. Reproductive maturity, fecundity, and size at harvest of brachyuran crabs, as well as other relevant, management-related biological characteristics are associated with external, morphometric features. Additionally, the relationships between various exoskeletal features have taxonomic value in many brachyuran groups, including the Geryonidae. This study examined the relationships between carapace length, carapace width, and total wet weight for male and female *C. fenneri* and *C. quinquedens* from the eastern Gulf of Mexico and compared findings with similar data for these species from the eastern Atlantic Ocean.

MATERIALS AND METHODS

Red and golden crabs were collected in August and September 1995 in conjunction with an EPA/Gulf of Mexico Program grant to investigate trace element contaminants in sediments and in selected tissues of *C. quinquedens*. Red crabs used in this study were collected west of Tampa, FL (27°46' N, 85°35' W) in 952 m and south of Pensacola, FL (28°17' N, 87°32' W) in 732 m. Golden crabs were captured at a single site west of Tampa, FL (27°48' N, 85°24' W) in 732 m. Crabs were trapped using twelve Fathoms Plus commercial crab traps which are designed to retain adult crabs and to prevent the retention of juvenile crabs. Capture protocol followed Waller et al. (1995). Crabs were maintained at sea in refrigerated seawater systems and returned to the laboratory alive. All weights and linear measurements were taken in the laboratory. Ovigerous females and crabs with missing appendages were not included in analyses. Carapace width (CW) was determined by measuring the distance between the tips of the fifth lateral spines. Carapace length (CL) was measured as the midline distance from the diastema between the rostral teeth to the posterior edge of the carapace. Carapace width and length were measured to the nearest millimeter with electronic calipers. A Sartorius electronic balance (model MP 9) was used to determine wet weight (Wt) in grams.

Statistical analyses were performed using StatGraphics® Plus Version 7.1 and Clinstat® computer software. The mean and standard deviation were calculated for each measured character for male and female crabs of both species. A t-test ($\alpha = 0.05$) was used to compare character means. An analysis of covariance procedure (ANCOVA, $\alpha = 0.05$) with carapace length as the covariate was used to test for significant differences between the sexes in the slopes and intercepts of the carapace width/carapace length relationship for both species. Analysis of

covariance was used to test for significant differences between the sexes in the slopes and intercepts of the weight/carapace length and weight/carapace width relationships for each species. Separate analyses were conducted using carapace length and carapace width as covariates. Data were log-log transformed for the weight analyses. In the figures of the weight/carapace length and weight/carapace width regressions, linear scales rather than logarithmic scales were used to aid in visual interpretations of relationships. The equations of Wenner et al. (1987), Erdman and Blake (1988), and Erdman (1990) for golden crabs, and the equations of Haefner (1978) for red crabs were solved over the size range of animals in the present study to determine whether their predicted measurements were within the 95 % prediction limits for crabs from the eastern Gulf of Mexico. Both Wenner et al. (1987) and Erdman (1990) predicted carapace length based on carapace width for *C. fenneri* from the Atlantic Ocean. To allow comparison of these characters between Gulf and Atlantic specimens, their methodology was followed and equations which predicted carapace length based on carapace width were derived and solved.

RESULTS

Chaceon fenneri

Means of carapace length (σ = 114 ± 10 mm, φ = 95 ± 7 mm), carapace width (σ = 142 ± 11 mm, φ = 118 ± 9 mm), and weight (σ = 787 ± 206 g, φ = 390 ± 242 g) were greater for males (n = 32) than for females (n = 13). Results of t-tests comparing the means of characters for males and females showed statistically significant differences for carapace length (t = -6.34, p = 6.29 x 10^{-7}), carapace width (t = -6.86, p = 2.04 x 10^{-8}), and weight (t = -9.39, p = 5.70 x 10^{-12}).

Coefficients of determination were high for CW/CL regressions for males (r^2 = 0.93) and females (r^2 = 0.97), indicating a strong linear relationship between carapace length and width for both sexes (Figure 1). When regressions of carapace width against carapace length were compared for males and females, no significant differences were found in the slopes or intercepts of the regression lines (slope F = 3.29, p = 0.08 ; intercept F = 4.13, p = 0.049). Thus, this relationship was considered equal for males and females. Coefficients of determination were high for the log-log transformed Wt/CL and Wt/CW regressions for males (r^2 = 0.96 and r^2 = 0.95, respectively) and females (r^2 = 0.96 and r^2 = 0.95, respectively). This indicated a strong exponential relationship between weight and carapace length and between weight and carapace width for both
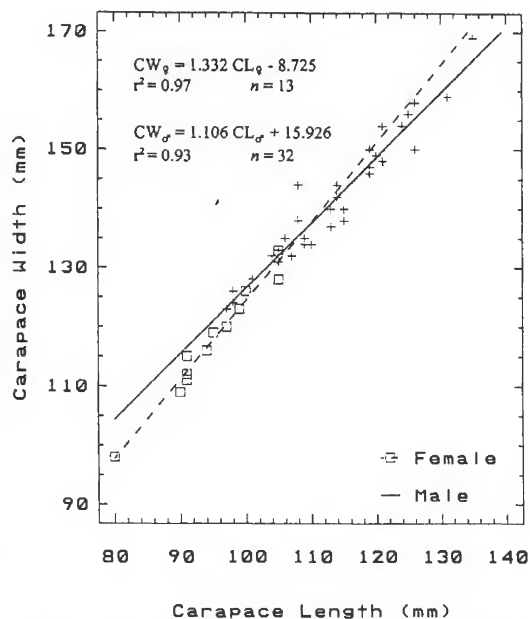

Figure 1. Regression of carapace width (CW) vs carapace length (CL) for male and female *C. fenneri*.

sexes (Figures 2 & 3). ANCOVA of the log-log transformed Wt/CL data showed no significant difference in the slopes of the regression lines (F = 0.37, p = 0.55); however, a significant difference was found in the intercepts (F = 46.63, p < 0.0001), indicating that for a given carapace length males were heavier than females. In contrast, the weight and carapace width relationship between males and females showed significant differences in both regression slopes and intercepts of the log-log transformed data (slope F = 8.40, p = 0.006: intercept F = 19.02, p < 0.0001). However, for a given carapace width within the size range of this study males were always heavier than females.

Chaceon quinquedens

Means of carapace length (σ = 107 ± 12 mm, φ = 95 ± 8 mm), carapace width (σ = 128 ± 13 mm, φ = 114 ± 9 mm), and weight (σ = 614 ± 185 g, φ = 416 ± 95 g) were greater for males (n = 49) than for females (n = 24). Results of t-tests to compare the means of characters for males and females showed statistically significant differences for carapace length (t = -4.92, p = 6.84 x 10^{-6}), carapace width (t = -5.19, p = 2.92 x 10^{-6}), and weight (t = -6.04, p = 6.29 x 10^{-8}).

Coefficients of determination were high for CW/CL regressions for males (r^2 = 0.94) and females (r^2 = 0.94),

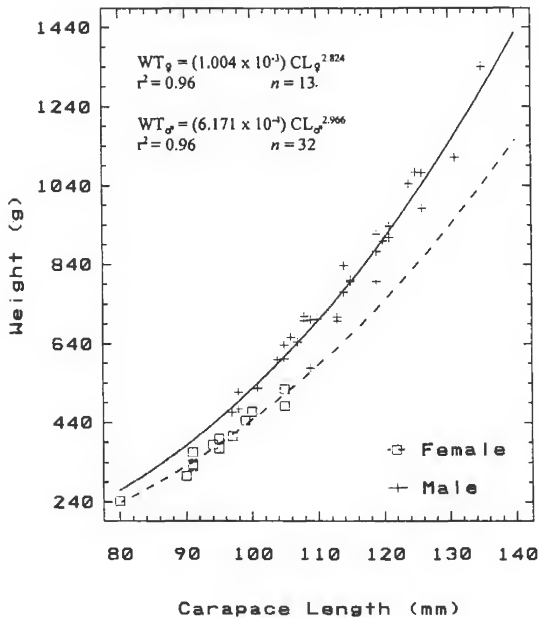Figure 2. Regression of weight (Wt) vs carapace length (CL) for male and female *C. fenneri.*

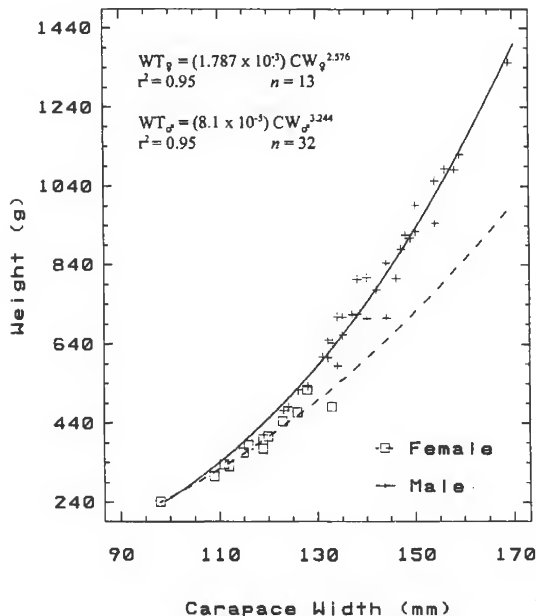indicating a strong linear relationship between carapace length and width for both sexes (Figure 4). When regressions of carapace width against carapace length were compared for males and females, no significant difference in the slopes or intercepts of the regression lines was found (slope $F = 0.18$, $p = 0.67$; intercept $F = 2.29$, $p = 0.13$). Thus, this relationship was considered equal for males and females. Coefficients of determination were high for the log-log transformed Wt/CL and Wt/CW regressions for males ($r^2 = 0.98$ and $r^2 = 0.94$, respectively) and females ($r^2 = 0.93$ and $r^2 = 0.89$, respectively), indicating a strong exponential relationship between weight and carapace length and between weight and carapace width for both sexes (Figures 5 & 6). ANCOVA of the log-log transformed Wt/CL and Wt/CW data showed no significant difference in the slopes of the regression lines (carapace length $F = 0.00$, $p = 0.98$; carapace width $F = 0.12$, $p = 0.73$). However, a significant difference was found in the intercepts (carapace length $F = 5.41$, $p = 0.023$; carapace width $F = 0.54$, $p = 0.47$), indicating that for a given carapace size male red crabs were heavier than females.
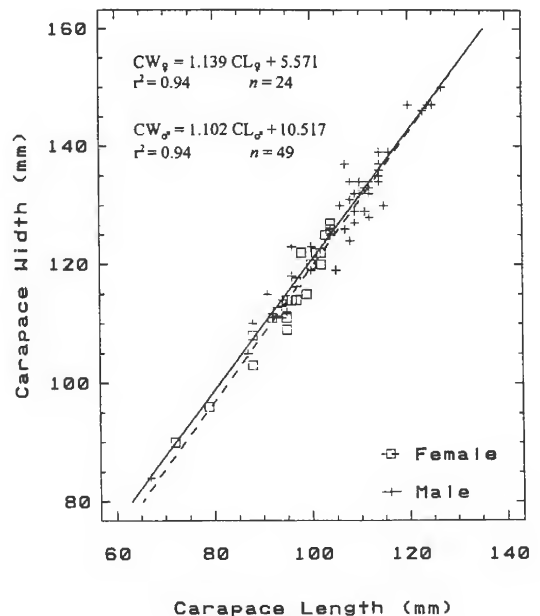

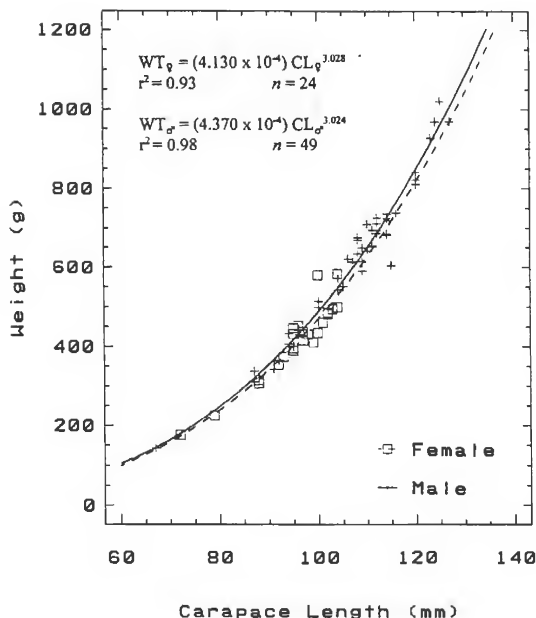Figure 3. Regression of weight (Wt) vs carapace width (CW) for male and female *C. fenneri.*

Figure 4. Regression of carapace width (CW) vs carapace length (CL) for male and female *C. quinquedens.*

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Figure 5. Regression of weight (Wt) vs carapace length (CL) for male and female *C. quinquedens.*

In figure 5:
$$WT_\female = (4.130 \times 10^{-4})\, CL_\female^{3.028}$$
$$r^2 = 0.93 \qquad n = 24$$
$$WT_\male = (4.370 \times 10^{-4})\, CL_\male^{3.024}$$
$$r^2 = 0.98 \qquad n = 49$$

Figure 6. Regression of weight (Wt) vs carapace width (CW) for male and female *C. quinquedens.*

In figure 6:
$$WT_\female = (1.840 \times 10^{-4})\, CW_\female^{3.083}$$
$$r^2 = 0.89 \qquad n = 24$$
$$WT_\male = (1.220 \times 10^{-4})\, CW_\male^{3.172}$$
$$r^2 = 0.94 \qquad n = 49$$

DISCUSSION

There were no significant differences in the carapace width/carapace length relationships between males and females for golden and red crabs in this study. Weight/carapace length and weight/carapace width relationships were each highly correlated for both males and females of each species. Our findings were generally consistent with studies of golden and red crabs from the Atlantic Ocean. Male golden crabs from the eastern Gulf of Mexico were larger and heavier than females per unit carapace width. Both Wenner et al. (1987) and Erdman and Blake (1988) found that mean carapace width and weight of golden crabs were greater for male than for female crabs collected off South Carolina and southeast Florida, respectively.

The equations of Wenner et al. (1987) and Erdman (1990) were solved to predict the carapace lengths of male and female golden crabs over the range of carapace widths observed in the present study. Without exception, their predicted carapace lengths fell within the 95 % prediction limits for carapace length of golden crabs from our study. Weight/carapace width relationships for male and female golden crabs were determined by Wenner et al. (1987) and Erdman and Blake (1988). The weight/carapace width relationships for male golden crabs in their studies were similar to relationships observed for male golden crabs
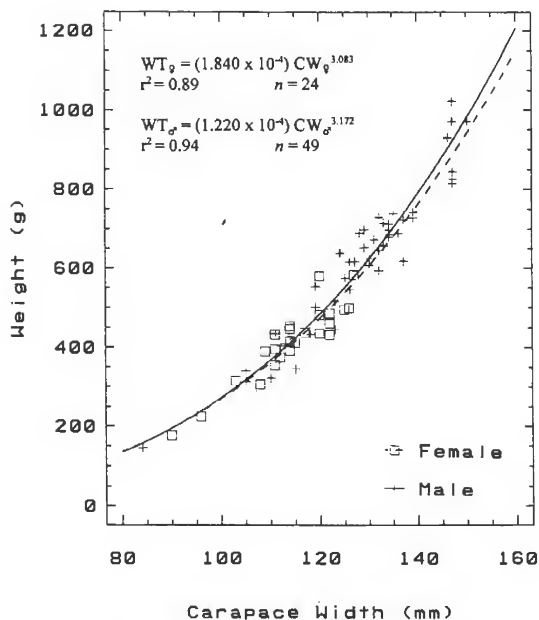
taken from the eastern Gulf of Mexico. Resultant weights based on selected carapace widths were within the 95 % prediction limits of weight for male golden crabs taken in the present study. Predicted weights for female golden crabs taken off southeastern Florida (Erdman and Blake 1988) were within the 95% prediction limits of weight for female golden crabs in the eastern Gulf of Mexico. Calculated weights using the equation of Wenner et al. (1987) were within our 95 % prediction limits for female golden crabs $\geq$ 121 mm CW; however, calculated weights were below our 95 % predictions for crabs < 121 mm CW. Of the measured parameters, carapace width and weight are the more variable, and this may account for this discrepancy. The location (sea or laboratory) and means by which weight was determined were not noted by Wenner et al. (1987).

Survey data from distributional studies of red crabs from Atlantic waters are in agreement with our size and weight data for red crabs in the Gulf of Mexico. Haefner (1978) noted that male red crabs taken from Norfolk Canyon, Virginia, were larger and heavier than females. Similar observations were made by Ganz and Herrmann (1975) for New England red crabs and by Stone and Bailey (1980) for red crabs on the western Scotian Shelf. Equations relating carapace width to carapace length and weight to carapace length for male and female red crabs were

provided by Haefner (1978). Predicted carapace widths for male and female red crabs from his study were within our 95 % prediction limits for this species. Weights derived for male and female crabs using his regression equations were comparable to our predicted weights and were within our 95 % prediction limits.

Acknowledging our small sample size for golden and red crabs, it would still appear that in regard to the size and weight relationships examined, there is little difference between Atlantic and Gulf populations.

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Zooplankton Variability and Copepod Species Assemblages from a Tropical Coastal Lagoon

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ZOOPLANKTON VARIABILITY AND COPEPOD SPECIES ASSEMBLAGES FROM A TROPICAL COASTAL LAGOON

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ABSTRACT Results of monthly zooplankton sampling, carried out from December 1990 to November 1991, are compared from three localities in the Mexican Caribbean. Two stations, Bojórquez, and Cuenca Norte, represent partially enclosed areas of the Nichupté Lagoon System in the northeastern region of the Yucatán Peninsula; a third station was located in adjacent neritic waters. At the neritic station, temperature was lower, salinity was higher, and variations in the two parameters smaller as compared to the two lagoon stations. Zooplankton abundance ranged from 3585.5 org./m³ at the neritic station to 18,742.7 org./m³ at Cuenca Norte. Considering all animals collected, decapod larvae (39%), copepods (28.7%) and ophiopluteus-echinopluteus larvae (22.8%) made the bulk of the catch. A total of 47 copepod species were recorded, of these, 14 were found at Bojórquez, 12 at Cuenca Norte and 42 at the neritic station. *Acartia tonsa* dominated the copepod population assemblage at Bojórquez (94.4%) and made important contributions at Cuenca Norte (34.5%) and in the neritic station (24.5%). *Paracalanus quasimodo* was most abundant at Cuenca Norte (40.3%) and contributed 20.9% at the neritic station. It is suggested that both, the high capture of *A. tonsa* in Bojórquez and the dominance of *P. quasimodo* at Cuenca Norte, is probably related with two factors: the anthropogenically nutrient-enriched condition of Bojórquez lagoon and the relatively higher breeding frequency of the chaetognath *Sagitta hispida* in Bojórquez. The highest abundance of zooplankters occurred at the stations within the lagoonal system, and the highest number of copepod species was found at the neritic station, where more stable conditions prevailed.

INTRODUCTION

Bojórquez lagoon, as part of the Nichupté Lagoon System (NLS), is a striking example of man's improper use of a coastal body of water. Jordán et al. (1978) reported oligotrophic conditions in the system, although with some symptoms of ecological deterioration. Subsequent studies by Reyes-Gómez (1988), González-López (1989), Merino et al. (1990) and Hermus (1992) showed that the NLS presented eutrophic conditions. Several factors contributed to this. The oceanic tidal range of 20 cm for this area of the Caribbean sea (instituto de Geofisica 1984) is further reduced to only 3 cm within the NLS (García-Krasovsky 1984). Water exchange in the NLS is consequently very low, and in spite of having two inlets, the system can be considered as "choked" according to Kjerfve's (1986) classification. Being located on the eastern end of the system, Bojórquez lagoon is further affected by its considerable distance from the two inlets and by a lack of continental runoff. Runoff is relatively important during the rainy period on the west side of the NLS (Merino et al. 1990), but does not reach Bojórquez. Thus, the only important freshwater input for Bojórquez is from local rainfall.

In the 1970's the construction of Cancún City, the most ambitious Mexican tourist resort in the Caribbean, brought additional stress to the lagoon. Dredging or refilling of parts of Bojórquez were carried out to permit boat navigation or provide tourist facilities. With increasing human population, domestic waste increased accordingly and the need for a sewage treatment facility became compulsory. A supposed "sewage treatment plant" was placed in the vicinity of Bojórquez and its high nutrient content discharge was released into the lagoon. Although sewage disposal has since been diverted to deep holes used as septic tanks, illegal sewage discharges or malfunctions of the treatment plant occasionally occur, such as when the amount of waste exceeds the plant capacity during the rainy period causing the overflow to enter the lagoon. Nutrient enrichment has promoted proliferation of macroalgae (Serviere 1986; Cúlhuac 1987; Hermus 1992) and although some efforts have been made to sanitize Bojórquez (harvesting the macroalgae for example), 25 years have elapsed since the initial sewage discharges and environmental conditions have not improved. At present, a project is underway for a water pumping system devised by Ruíz-Rentería et al. (1994) to bring sea water into Bojórquez.

The importance of this work, beside the fact that zooplankton community studies in this area are extremely scarce, is that we will be able to monitor the evolution in composition and abundance of the zooplankton community once the pumping system is working. We will have the information before, during and after the system has been installed.

In this paper, monthly copepod species assemblages and fluctuations in the abundance and composition of zooplankton groups are compared for three regions: (1) Bojórquez lagoon, (2) Cuenca Norte, an area at the northern end of the NLS but nearer to the tidal inlet, and (3) the neritic waters north of the NLS.

Study Area

The Nichupté Lagoon System (NLS) is located in the non-mountainous northeastern region of the Yucatán Península, 21°07'N and 86°46'W (Figure 1). The climate of this area is subhumid and warm (lowest temperatures are higher than 18°C), with the main rainy season in summer
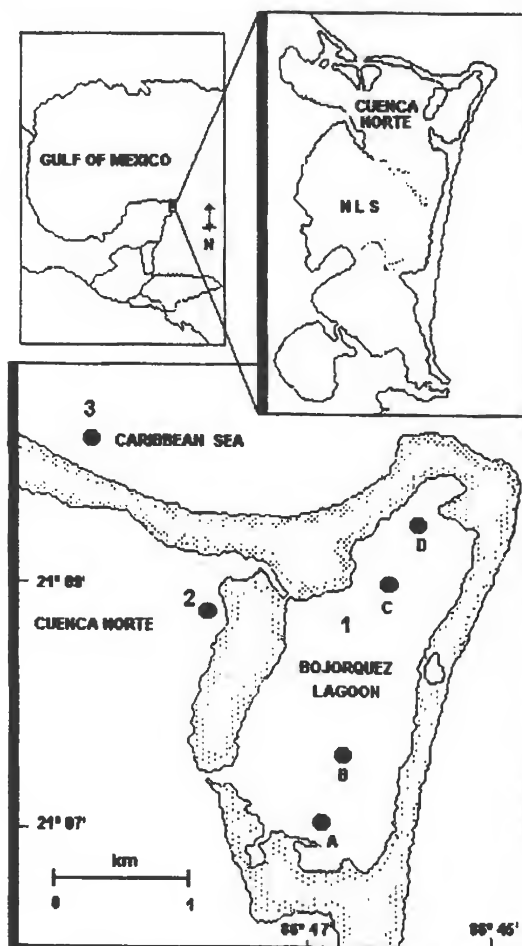

Figure 1. Study area and sampling locations in the Nichupté Lagoon System (NLS). 1 Bojórquez, 2 Cuenca Norte, and 3 neritic station. Note that Bojórquez contains four sampling sites.

and moderate rainfall in winter (type AW1 (X') (i') g of García 1964). The NLS was originally oligotrophic as are the waters of the Caribbean sea, and although the system (type IV-B of Lankford 1977) at present is surrounded by tourist facilities (hotels, scuba diving facilities, sport fishing fleets, etc.), it was originally bordered by mangrove vegetation. Particular features in the area are a highly porous and permeable sóil (Butterlin 1958; López-Ramos 1974) allowing a rapid filtration of rain, and a lack of land runoff. Rivers frequently found in other lagoon systems are absent here, there being instead subterranean water and "cenotes" (karstic water deposits).

Three climatological regimes, "nortes" (strong northern winds blow in the area), dry and rainy, are reported annually in this area (Merino and Otero 1991). However, year to year variations in the length of these periods are also recorded. During the present survey, the "nortes" period extended from December to March, followed by a dry period from April to July, and a rainy period from August to November.

MATERIALS AND METHODS

Zooplankton samples and hydrographic data (salinity and temperature) were collected monthly at three sampling stations from December 1990 to November 1991. Station 1 (Bojórquez Lagoon) with a 1.5 m mean depth, consisted of four sampling sites (1A-1D). Results on abundance and composition of the zooplankton at these sites were pooled and mean values were reported for this area. Station 2 (2.5 m depth) was situated in the northern part of the NLS, locally known as Cuenca Norte. Station 3 (4 m depth) was neritic, at ca. 3 km offshore from the Cancún inlet (Figure 1). Due to bad weather conditions, samples were not collected in January at this station.

Near-surface tows were made between 0900 and 1200h using a conical plankton net (0.42 m diameter and 1.30 m length) with a 330 μm mesh. This mesh size was selected after several trials conducted to determine the rapidness of clogging and the efficiency in collecting most of the fauna. A General Oceanics digital flowmeter was attached to the mouth of the net to estimate volume of water filtered (m^3). Collections were taken in a circular path at ca. 1.5 -2 knots for five minutes. Zooplankton samples were preserved in 5% buffered (lithium carbonate) formalin.

Floating vegetation and its associated fauna was accidentally collected together with the zooplankton mainly at Bojórquez. This associated fauna and zooplankton were dislodged by repeatedly rinsing and shaking the algae collected during the tows. Subsampling was performed following Russell's method (1927), and considering Omori

and Ikeda's (1984) recommendations for having a representative aliquot in which at least 300 organisms per sample should be analyzed. Subsequent aliquots were taken when the previous subsamples did not yield enough animals or, instead, the whole sample was analyzed. Zooplankton was identified to major taxonomic groups, and the highly abundant copepods to species, when possible. Data were standardized to organisms per m³ based on numbers counted and volume of water filtered.

RESULTS

Temperature and salinity

Surface temperature recorded during the present study ranged between 25.7 and 32.3°C. Greater fluctuations were recorded at Bojórquez (SD± 2.18) than at Cuenca Norte (SD± 2.06), or the neritic station (SD±1.11). Maximum values were recorded in July and August for the former two areas and in September for the latter (Figure 2a).

Salinity ranged from 28.30 to 36.49 o/oo year round. Highest values were recorded in June at the neritic station (SD± 1.44), while lowest values were observed in November at Cuenca Norte (SD± 1.85). At Bojórquez, intermediate salinity values (SD± 1.78) were recorded (Figure 2b).

Temperature and salinity values were lower from December to March (nortes) when cold, strong northern winds blew in the area. Both parameters increased progressively from April to July (dry period) until reaching a peak in August, just before the rainy period started (Figure 2a,b).

Zooplankton taxa

A mean of 9964.7 org./m³ were collected from the three locations. The highest abundance of zooplankters was recorded at Cuenca Norte (18743 org./m³), compared to Bojórquez (7563 org./m³) or the neritic station (3585 org./m³). Abundance also varied seasonally. At Bojórquez (Table 1) there was clearly a higher abundance during the rainy period (4416 org./m³), followed by the "nortes" (2400 org./m³), whilst during the dry period only 747 org./m³ were caught. At Cuenca Norte (Table 2), the dry (6630 org./m³), rainy (6497 org./m³) and "nortes" (5617 org./m³) periods had similar abundances. In the neritic station (Table 3) the "nortes" period was clearly more productive (2515 org./m³), than the dry (944 org./m³) or rainy periods (127 org./m³).

Changes in the zooplankton composition were also recorded. Abundance of the zooplankters mainly consisted of decapod larvae, copepods and ophiopluteus-echinopluteus larvae, however not in this same order for the three

locations. Copepods were, by far, the most abundant group at Bojórquez (Table 1), comprising 81.7% of the total catch, followed by decapod larvae (4.9%) and ophiopluteus-echinopluteus larvae (3.9%). Nineteen other taxa made up the remaining percentages; of them, protozoans and nematodes were the most important components of the plankton year round. At Cuenca Norte (Table 2), decapod larvae (57.2%), ophiopluteus-echinopluteus larvae (23.0%) and copepods (11.9%), comprised more than 90% of the total population. Other important groups at this area were sergestids (*Lucifer*) and chaetognaths. At the neritic station (Table 3), ophiopluteus-echinopluteus larvae (61.1%), decapod larvae (15.9%) and fish eggs (7.7%) were the main contributors. Cirripeds and copepods constituted 5.3% and 5.7% respectively.

Copepod species

A total of 44 nominal species including representatives of Calanoida, Cyclopoida, Poecilostomatoida, Harpacticoida and Monstrilloida were recorded. Of these, 41 species were collected at the neritic station, 13 at Bojórquez, and 10 at Cuenca Norte. Six species were common at all locations, three were exclusively found at Bojórquez, and one species was restricted to Cuenca Norte (Table 4).

Acartia tonsa, *Paracalanus quasimodo*, and *Labidocera spp.* dominated the populations assemblages throughout the year. They comprised 97.2% of all copepods taken, and with the exception of *A. tonsa*, not recorded at the neritic station in June, they were caught at all times. Harpacticoids were also found at all three locations, but their abundance was notable only at Bojórquez (Table 4).

Acartia tonsa made up the bulk of the copepod assemblage, particularly at Bojórquez, where it accounted for 94.4% of the total catch (Table 4). Lowest numbers were recorded at the neritic station where the mean percentage was 24.5. At Cuenca Norte, *Paracalanus quasimodo* dominated the copepod assemblage (40.3%), while at the neritic station it accounted for 20.9%. The lowest numbers for this species occurred at Bojórquez with only 2.9%. *Labidocera* spp. were more abundant at Cuenca Norte (22.2%) and at the neritic station (10.9%) than at Bojórquez (1.4%; Table 4). The remaining copepod species were recorded in low numbers, except for the harpacticoid, *Miracia efferata* (21.2%) and the poecilostomatoid, *Farranula gracilis* (7.1%) at the neritic site (Table 4).

DISCUSSION

Temperature differences among sampling sites are probably related to the particular hydrological characteristics at the three locations. Thus, the highest (rainy period) and
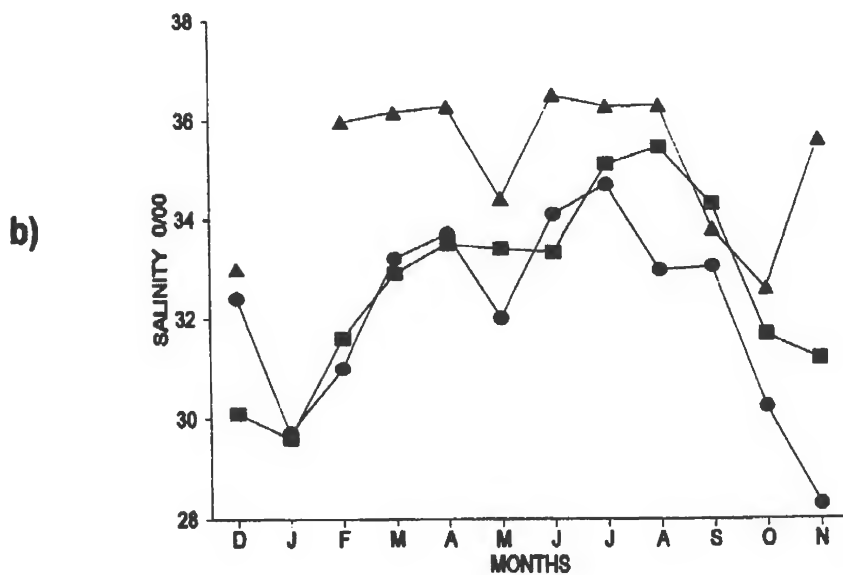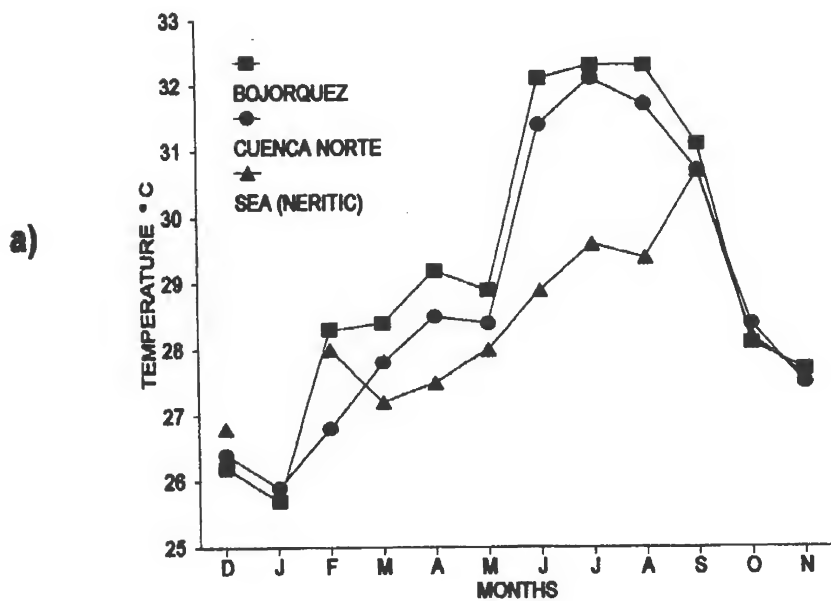
Figure 2 Annual variation of a) temperature and b) salinity at two stations in the NLS and at the adjacent neritic station. Mean values (n=4) are given for Bojórquez.

TABLE 1

Mean monthly standardized abundance (org./m³) of zooplankton by taxa collected at the four sampling sites (1a-1d) in Bojórquez. Values listed under taxa are annual mean values. % = percent of total mean values.

TAXA	D	J	F	M	A	M	J	J	A	S	O	N	Taxa totals	%
PROTOZOA	1.00	0.37	1.00	3.80	0.00	1.30	4.80	2.80	4.80	72.20	18.50	48.20	158.77	2.09
MEDUSAE	1.60	1.10	23.40	1.00	0.50	0.28	2.10	0.87	2.80	7.00	16.60	7.60	64.85	0.85
NEMATODA	0.50	0.37	0.19	17.50	0.00	0.04	3.10	0.06	1.60	0.67	0.00	0.60	24.63	0.32
POLYCHAETA	0.25	0.74	0.00	4.00	0.00	0.70	1.90	0.66	0.25	3.40	2.70	6.00	20.60	0.27
GASTROPODA	23.50	9.80	9.20	8.70	0.95	8.30	4.20	5.80	8.90	4.60	5.50	33.00	122.45	1.61
NUDIBRANCHIA	0.00	0.00	0.00	0.00	0.00	0.00	49.00	0.00	0.00	0.00	0.00	0.30	49.30	0.65
PELECYPODA	0.15	0.00	0.00	0.00	0.00	0.08	0.35	0.02	0.00	0.00	0.00	0.00	0.60	0.01
OSTRACODA	0.12	0.92	0.00	11.40	0.00	1.70	1.00	3.50	0.47	7.20	7.00	1.00	34.31	0.45
COPEPODA	489.50	367.50	563.75	675.75	46.50	9.30	84.90	199.00	810.70	1257.70	1053.80	619.25	6177.65	81.68
CIRRIPEDIA	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.72	2.10	0.00	4.00	1.40	8.57	0.11
CUMACEA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.30	1.40	0.01
TANAIDACEA	0.27	0.00	0.75	6.70	0.00	2.70	3.10	0.27	0.12	0.00	4.20	1.20	19.31	0.25
ISOPODA	0.07	0.00	0.38	0.00	0.24	0.03	0.73	0.08	0.12	0.00	0.00	0.24	1.89	0.02
AMPHIPODA	0.55	0.67	0.00	3.00	0.12	0.71	3.90	0.83	0.62	0.56	0.55	0.00	11.51	0.15
DECAPODA (LARVAE)	18.50	9.70	9.30	21.90	1.80	18.20	39.30	3.30	101.50	18.40	109.65	21.00	372.55	4.92
SERGESTIDAE	0.82	0.00	0.00	2.10	0.12	5.40	0.00	0.00	0.00	0.00	2.00	0.87	11.31	0.14
SIPUNCULIDA	0.00	0.00	0.00	0.00	0.00	0.00	3.40	2.00	1.20	0.00	1.00	0.00	7.60	0.10
CHAETOGNATHA	6.30	11.00	5.90	3.10	2.10	4.10	15.30	5.10	39.50	19.00	13.50	13.00	137.90	1.82
ECHINODERMATA	20.50	11.70	29.20	1.10	15.50	0.92	143.50	33.80	0.00	12.90	4.00	23.50	296.62	3.92
UROCHORDATA	2.42	1.54	6.81	0.55	0.36	0.69	0.94	1.26	0.70	0.00	0.00	9.25	24.52	0.32
FISH EGGS	1.90	0.86	3.50	1.10	0.00	2.40	0.00	0.06	1.50	0.00	3.20	1.20	15.72	0.20
FISH LARVAE	0.26	0.00	0.26	0.15	0.00	0.02	0.08	0.03	0.06	0.09	0.11	0.03	1.09	0.01
Monthly totals	568.21	416.62	653.64	761.85	68.19	56.87	361.60	260.16	976.94	1404.82	1246.31	787.94	7563.15	

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TABLE 2

Total standardized abundance (org./m^3) of zooplankton taxa collected at Cuenca Norte. % = percent of taxa totals.

TAXA	D	J	F	M	A	M	J	J	A	S	O	N	Taxa totals	%
PROTOZOA	3.00	0.00	0.00	0.00	1.70	0.00	0.00	1.20	0.00	0.00	2.50	1.20	9.60	0.05
MEDUSAE	4.00	1.00	5.50	5.12	0.30	0.00	2.10	0.00	5.10	8.23	4.00	4.20	39.55	0.21
POLYCHAETA	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.00	1.20	3.70	0.02
GASTROPODA	0.00	3.00	0.00	0.00	1.70	0.00	20.00	2.40	0.00	0.00	1.70	3.00	31.80	0.17
CLADOCERA	0.00	0.00	0.00	0.00	0.00	0.00	2.50	4.20	4.40	0.00	0.00	0.00	11.10	0.06
OSTRACODA	0.00	0.00	0.00	0.00	0.00	1.60	7.50	0.00	0.00	0.00	0.00	0.00	9.10	0.04
COPEPODA	274.00	160.00	91.00	298.00	453.00	242.00	295.00	92.00	74.00	58.00	125.00	74.00	2236.00	11.93
CIRRIPEDIA	3.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30	0.00	2.00	5.40	16.70	0.09
DECAPODA (LARVAE)	69.00	48.40	34.80	362.00	510.50	347.56	3487.50	63.60	4848.90	602.50	325.00	28.00	10727.76	57.23
SERGESTIDAE	54.00	0.00	0.00	117.00	295.00	333.00	22.50	8.30	0.00	0.00	3.30	6.50	839.60	4.48
SIPUNCULIDA	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.60	0.00	0.00	0.00	1.20	6.80	0.03
CHAETOGNATHA	49.00	5.00	9.60	12.50	15.80	44.30	82.50	49.40	133.30	17.90	0.30	31.00	450.60	2.40
ECHINODERMATA	36.31	136.00	219.00	5.00	154.00	9.80	45.00	11.30	0.00	0.00	52.50	49.00	4312.60	23.00
UROCHORDATA	0.00	0.00	4.20	0.00	0.00	1.60	5.00	0.00	0.00	0.00	0.00	0.00	10.80	0.05
FISH EGGS	0.00	0.00	5.50	2.50	3.60	3.30	0.00	0.60	20.00	0.00	0.80	0.00	36.30	0.19
FISH LARVAE	0.06	0.00	0.00	0.07	0.30	0.00	0.01	0.20	0.07	0.05	0.02	0.00	0.70	0.00
Monthly totals	4087.06	357.40	369.60	802.19	1435.90	983.16	3977.11	233.80	5088.07	686.68	517.12	204.70	18742.71	
	⌞——NORTES——⌟			⌞———DRY——⌟					⌞——RAINY——⌟					
	5616.25			6629.97					6496.57					

TABLE 3

Total standarized abundance (org./m³) of zooplankton taxa collected at the neritic station. % = percent of taxa totals.

TAXA	D	F	M	A	M	J	J	A	S	O	N	Taxa totals	%
PROTOZOA	13.20	21.80	0.45	7.80	0.00	0.50	7.40	0.60	1.30	0.70	1.00	54.75	1.52
MEDUSAE	1.30	3.50	0.30	0.02	0.10	0.02	0.80	0.10	0.06	0.40	0.30	6.9	0.19
NEMATODA	0.00	2.30	0.10	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	2.8	0.08
POLYCHAETA	0.00	0.00	0.07	0.00	0.00	0.20	0.80	0.10	0.00	0.02	0.00	1.19	0.02
GASTROPODA	0.00	3.40	0.30	0.06	0.00	0.10	0.80	0.20	0.10	0.10	0.80	5.86	0.16
CLADOCERA	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.20	0.00	0.02	0.00	0.42	0.01
OSTRACODA	0.00	4.60	0.14	0.00	0.00	0.03	0.00	0.00	0.04	0.06	0.05	4.92	0.13
COPEPODA	74.90	63.40	0.70	1.00	23.30	1.50	4.40	8.12	5.30	19.00	1.00	202.62	5.65
CIRRIPEDIA	2.60	0.00	0.00	1.22	0.00	0.00	181.00	0.04	0.06	4.80	0.00	189.72	5.29
CUMACEA	38.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38	1.05
TANAIDACEA	0.00	3.40	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	3.47	0.09
AMPHIPODA	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.14	0
DECAPODA (LARVAE)	22.40	6.90	2.40	1.16	495.90	0.90	16.40	7.30	6.95	8.30	0.20	568.81	15.86
SERGESTIDAE	5.30	2.30	0.10	0.04	6.50	0.00	0.00	0.00	0.00	0.30	0.00	14.54	0.4
CHAETOGNATHA	10.50	3.40	0.02	0.30	1.10	0.00	0.50	0.50	0.50	0.10	0.00	16.92	0.47
ECHINODERMATA	1689.00	486.00	0.02	0.02	0.00	0.00	3.30	0.00	0.00	11.10	1.90	2191.34	61.11
UROCHORDATA	0.00	3.45	0.05	0.04	1.13	0.23	0.00	0.00	0.00	0.04	0.20	5.14	0.14
FISH EGGS	38.20	0.00	9.50	1.20	10.90	0.40	172.10	12.30	13.10	18.80	0.30	276.8	7.72
FISH LARVAE	0.10	0.07	0.50	0.00	0.00	0.03	0.40	0.00	0.00	0.04	0.00	1.14	0.03
Monthly totals	1895.50	604.52	14.71	12.98	538.93	4.44	387.90	29.46	27.41	63.78	5.85	3585.48	
	├── NORTES ──┤ 2514.73			├── DRY ──┤ 944.25			├── RAINY ──┤ 126.5						

TABLE 4

Mean annual standardized abundance (org./m³) of copepod species collected at the three stations.
Values given for Bojórquez represent means from four sites. * = mean percentage for two species of *Labidocera*
and associated copepodid stages.

	Bojorquez		C . Norte		Sea (Neritic)	
	Org./ m³	%	Org./ m³	%	Org./ m³	%
Calanoida						
Acartia tonsa	6724.60	94.4	775.00	34.50	49.73	24.50
A. spinata					6.42	
Pacalanus quasimodo	204.30	2.9	883.00	40.3	42.35	20.9
Acrocalanus longicornis					2.27	
Nannocalanus minor					0.02	
Neocalanus gracilis						0.02
Undinula vulgaris					0.56	
Clausocalanus arcuicornis					0.02	
C.furcatus					2.01	
Calocalanus pavo					0.48	
C.pavoninus					0.24	
Subeucalanus crassus					0.02	
S.pileatus					0.07	
Mecynocera clausi					0.02	
Candancia bipinnata					0.02	
Calanopia americana	9.40		29.00		4.90	
Labidocera mirabilis	46.10		34.00		0.16	
L.scotti	7.60	1.4*	124.00	22.2*	2.38	10.9*
L.spp (copepodids)	34.50		299.00		19.63	
Pontellina plumata						0.02
Temora stylifera					0.41	
T.turbinata			1.60		0.27	
Scolecithrix bradyi						0.02
Pseudodiaptomus cockeri			0.60			
Cyclopoida						
Oithona nana	10.90	5.3	1.00		0.02	
O. plumifera					1.06	
O. setigera					0.02	
O. oculata	0.40					
O. simplex	0.40					
O. sp	1.70		3.00			
Poecilostomatoida						
Ratania sp	0.40					
Corycaeus amazonicus	0.90		53.00	2.4	4.73	2.3
C.flaccus						0.02
C.latus					0.06	
C.subulatus	0.70				0.23	
C.speciosus					0.85	
C.sp					0.06	
Farranula gracilis			1.00		14.49	7.1
Oncaea media					0.02	
O.mediterranea					0.02	
O.venusta					3.05	
Sapphirina nigromaculata					0.02	
Harpacticoida						
Harpacticoids	82.00	1.1	4.00		1.21	
Clytemnestra scutellata					0.02	
Microsetella rosea					0.62	
Miracia efferata					43.04	21.2
Monstrilloida						
Thaumaleus sp	0.20				0.58	

lowest ("nortes") temperature values, i.e. widest variations, were observed at the shallow Bojórquez Lagoon, whereas the other, deeper areas presented accordingly more stable temperature values.

Salinity was usually lower at Cuenca Norte, especially from the beginning to the end of the rainy period (August-November), possibly due to runoff or the presence of water springs in the area (Merino et al. 1990). In contrast, the highest salinity values and lowest variations were recorded at the neritic station, indicating a more stable environment.

In comparing zooplankton abundances from the three sampling sites, seasonal differences were noted usually because of the high capture of a single taxon. At Bojórquez, the highest abundance was recorded during the rainy period due primarily to large numbers of copepods. At the neritic station, a single catch of mainly entangled masses of ophiopluteus-echinopluteus larvae made the "nortes" the most abundant period. Cuenca Norte showed similar abundances during the three climatic periods, with slightly higher captures during the dry period due to the combined catch of decapods, copepods and sergestids (*Lucifer*). It should be noted that, while copepods were regularly caught at the three sampling sites throughout the year, in the case of the other taxa, sporadic large captures of one group influenced the overall abundance at periods other than the rainy period.

The scarcity of previous zooplankton studies in the area makes it difficult to discuss in a comparative sense, the results found in this work. A preliminary report on the plankton population in the Nichupté Lagoon System during the dry and rainy seasons by Alvarez-Cadena et al. (1996a) revealed a major catch of zooplankton during the rainy season. Similarities were also encountered when comparing studies carried out in adjacent waters. Gasca and Castellanos (1993) found a higher zooplankton biomass in October (rainy period) for the Bahía de Chetumal. Segura-Puertas and Ordóñez-López (1994), studying the medusan fauna from the Campeche Bank and the Mexican Caribbean, also recorded higher values of abundance and species composition during the rainy season.

Copepods, decapod larvae and echinoderms were the most numerous and frequently recorded groups in this study. Copepods strongly dominated at Bojórquez while decapod larvae dominated at Cuenca Norte and were second in abundance at the neritic and Bojórquez stations, with lowest catches occurring at the latter. Due to a single massive catch in December, echinoderms dominated at the neritic station (1689 org./m³). Results of the present study agree with a previous report by Suárez and Gasca (1990), who found decapod larvae (45-55%) and copepods (30-35%) to be the dominant groups in Bahía de Ascensión,

a region to the south of the study area.

The number of copepod species at Bojórquez was similar to Cuenca Norte (12 and 11 respectively) and increased substantially to 41 at the neritic station, even though our sampling effort at Bojórquez was four times that at the other two locations. This confirms the generality, as reported by Margalef (1969) and Reeve (1975), that tropical lagoons have lower species diversity as compared to adjacent oceanic environments.

Acartia tonsa was the major component of the copepod assemblage in Bojórquez and the neritic sites as has been reported in other estuarine environments such as San Diego Bay (Esterly 1905), Cape Hateras, North Carolina, and southern Texas (Turner 1981). The species is well adapted to these habitats, despite eutrophication or pollution from human activities as in Mazatlán, Sinaloa, México (Alvarez-Cadena and Cortés-Altamirano 1990) or Guayanilla, Bay, Puerto Rico (Youngbluth 1976).

Acartia tonsa has been reported as euryhaline and eurythermic, and usually the dominant form in other Mexican estuarine environments such as Agiabampo, Sonora (Zamora-Sánchez 1974), Mar Muerto, Oaxaca (Escudero-Díaz 1975) and El Verde, Sinaloa (Hendrickx and Sánchez-Osuna 1983). According to Tester and Turner (1991), the success of the species may be due to the naupliar stages' tolerance to a wide salinity range. They proposed that the dominance of *A. tonsa* was a function of the physiology of the nauplii rather than of the adult.

In comparing the abundances of *Acartia tonsa* in Bojórquez and *Paracalanus quasimodo* in Cuenca Norte, it is possible to detect factors at these two sites that may account for the differences. As mentioned before, the waters of Bojórquez have a high nutrient content due to human influence. Fulton (1984), in experimental conditions, reported that an increase in nutrient concentration was associated with both an incremental increase in numbers of *A. tonsa* and a steady decline in the abundance of *Paracalanus crassirostris*, a sibling species of *P. quasimodo* reported here. Another possible reason might be predation pressure from chaetognaths, which are known to be important copepod predators (Feigenbaum and Maris 1984; Ohman 1986; Alvarez-Cadena 1993). In studying the chaetognaths of the NLS, Alvarez-Cadena et al. (1996b) found a single species, *Sagitta hispida* Conant, at Cuenca Norte and Bojórquez. Apparently this species reproduces more frequently at Bojórquez because of higher temperatures; this correlation with temperature has been found elsewhere for other species (φresland 1983, 1985; Sameoto 1971, 1973; Tande 1983). A rapid generation time implies either a higher frequency of small, young immature animals or that adults mature at a smaller size.

Both of these population characteristics were evident for the chaetognaths at Bojórquez, where the dominant maturation stage, gonadic stage I, was smaller there (2.96 mm annual mean size) than at Cuenca norte (4.18 mm). Prey size is known to be correlated with head width in chaetognaths (Pearre 1980), thus it is likely that smaller prey will be more readily removed from the population at Bojórquez. Thus, the smaller *P. quasimodo* is susceptible to predation at all stages, while *A. tonsa* is more at risk only during the younger stages.

To enhance the value of this work, more studies are needed for a better understanding of planktonic associations and assemblages in tropical environments. Bojórquez lagoon is an excellent natural laboratory where these associations could be monitored and, at the same time, it serves as an example of how easy an oligotrophic system can be damaged.

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Observations on Mass Mortalities of the Sooty Eel, *Bascanichthys bascanium*, and the Speckled Worm Eel, *Myrophis punctatus*, Associated With a Fish Kill in the Mississippi Sound

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OBSERVATIONS ON MASS MORTALITIES OF THE SOOTY EEL, *BASCANICHTHYS BASCANIUM*, AND THE SPECKLED WORM EEL, *MYROPHIS PUNCTATUS*, ASSOCIATED WITH A FISH KILL IN THE MISSISSIPPI SOUND

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ABSTRACT Mass mortalities of the sooty eel, *Bascanichthys bascanium*, and the speckled worm eel, *Myrophis punctatus*, were observed in association with a fish kill which occurred the morning of 18 June 1994 on the south shore of Deer Island, a nearshore barrier island located off Biloxi, Mississippi. *B. bascanium* and *M. punctatus*, as well as other fishes, were found dead and dying near the shore in reddish-brown water and along a lengthy stretch of fringing sandy beach. Both species of eels are infrequently reported from Mississippi waters but were the most abundant fishes recorded from the kill. A visual census conducted along ~1.6 km of shoreline and partially submerged tidal flat estimated eel mortalities at 8,000 individuals. The presence of highly discolored water and the lethargic behavior displayed by live eels and other fishes at the site of the kill suggested the episode may have been related to a localized phytoplankton bloom.

INTRODUCTION

Two species of the circumglobal ophichthid eel genus *Bascanichthys* Jordan and Davis, *B. bascanium* (Jordan) and *B. scuticaris* (Goode and Bean), are reported from the Gulf of Mexico (Leiby and Yerger 1980). Both species occur inshore and in shallow bays, however, only *B. bascanium* has been reported to occur off Mississippi (Leiby and Yerger 1980). The speckled worm eel, *Myrophis punctatus* Lütken, also occurs in nearshore waters of the Gulf of Mexico (Joseph and Yerger 1956; Springer and Woodburn 1960) and occasionally enters fresh water (Gunter 1956; Hoese and Moore 1977). According to Hoese and Moore (1977), only the juveniles of *M. punctatus* are found inshore, however, McCosker et al. (1989) reported that the normal locality for *M. punctatus* is inshore waters.

In a review of the taxonomic history of the genus *Bascanichthys* in the western Atlantic Ocean, Leiby and Yerger (1980) reported only 9 specimens of *B. bascanium* in available collections from Mississippi waters, and presented the only known published account of the occurrence of *B. bascanium* off Mississippi. *B. bascanium* was not collected during an extensive fisheries sampling program conducted in Mississippi coastal waters during 1982-95 by personnel of the Gulf Coast Research Laboratory, Ocean Springs, Mississippi (James Warren, personal communication). Only 74 specimens of *Myrophis punctatus* were collected during the same 14-year project, and Christmas and Waller (1973) reported they collected only one speckled worm eel from Mississippi waters during a study of estuarine fishes conducted during 1968-69.

With few exceptions (Gunter and Lyles 1979; Christmas and Waller 1973) the mortalities of specific fishes associated with "fish kills" which have occurred in Mississippi coastal waters have not been reported in the scientific literature, and none of the published reports identified the sooty eel and the speckled worm eel as components of the dead fish fauna. Considering the uncommon status ascribed *B. bascanium*, locally, and the infrequently reported occurrence of *M. punctatus* in local field collections, observations of mass mortalities of both species associated with a fish kill in Mississippi waters were considered noteworthy.

The fish kill we report here occurred on 18 June 1994 along the southern shoreline of Deer Island, an uninhabited nearshore barrier island located off Biloxi, Mississippi. Deer Island borders the Mississippi Sound on its south shore and the Bay of Biloxi on its north shore (Figure 1). The island is 6.4 km in length and 0.4 km at its widest point and is accessible only by water. Observations on the fish kill per se are less complete than is desirable, but in view of the relative absence of published local accounts on this subject it seemed worthwhile to present them in some detail.

METHODS

On 18 June 1994 at 0900 h, one of us (RPD) encountered a fish kill in progress along the south beach of Deer Island. Later (1100 h) during the same day, both authors visited the site of the kill and made various qualitative observations during an investigation of the central portion of the island's southern shoreline.

A visual survey was conducted along a randomly selected stretch (~1.6 km) of the island's south shoreline in order to investigate the magnitude of the kill and to ascertain which species were affected. With the exception
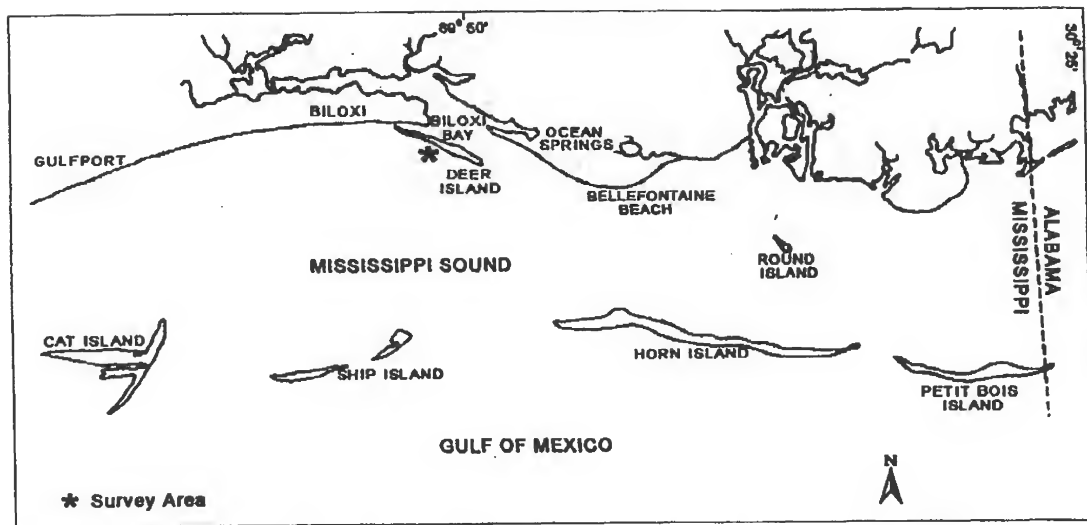
Figure 1. Map of the Mississippi Sound showing the location along the southern shoreline of Deer Island where mass mortalities of *Bascanichthys bascanium* and *Myrophis punctatus* were observed.

of eels, only the fishes which were washed-up on the beach or which were stranded at the water's edge were included in our initial survey. Fishes were identified in the field, and their numbers were estimated. Due to the extraordinarily high number of eels observed, another visual survey was conducted at two locations along the 1.6 km of shoreline, considered representative of the affected area, specifically for the purpose of obtaining a reasonable estimate of the number of eels present. The survey consisted of counting the approximate number of eels along two transects established perpendicular to the beach and located ~0.8 km apart. Each transect extended from the mark of recent high tide on the beach seaward across the submerged tidal flat for a distance of ~50 m, the point at which the discolored water prohibited visibility of the seafloor. The number of eels observed per m² of substrate along the length of each transect was noted. These values were used to estimate the total number of eels affected by the kill along the 1.6 km section of the island's south shore. The expansion formula used to estimate total numbers of dead/dying organisms (Harper and Guillen 1989) was:

$$\frac{\text{km of beach examined x 1000 x fish counted}}{\text{Sum length of transects (m)}}$$

On-site identification of eels was not feasible, thus specimens (dead and dying) were randomly collected along the transects and throughout the survey area for laboratory identification. Specimens were later preserved in 10% buffered formalin.

RESULTS

An investigation conducted at the site of the kill revealed substantial numbers of fish and a few (<50) blue crabs (*Callinectes sapidus*) dead and dying near and along the shore in reddish-brown water and along a lengthy stretch of fringing sandy beach.

Most of the fish were found crowding the water's edge and were either floating or lying on the bottom, and most of those were dead. Fishes included in our shoreline assessment were: Atlantic stingray (*Dasyatis sabina*), gulf menhaden (*Brevoortia patronus*), hardhead catfish (*Arius felis*), pinfish (*Lagodon rhomboides*), croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), stargazer (*Astroscopus y-graecum*), striped burrfish (*Chilomycterus schoepfi*), southern flounder (*Paralichthys lethostigma*), blackcheek tonguefish (*Symphurus plagiusa*), hogchoker (*Trinectes maculatus*) and eels. *D. sabina*, *A. y-graecum*, *C. schoepfi* and *P. lethostigma* were each represented by fewer than 5 specimens, whereas we estimated the number of individuals for each of the other species encountered, with the exception of the eels, to range between 50-100. Small croaker, hardhead catfish and spot were among the most numerous fishes observed, however, most striking by far was the vast number of eels, later identified as the sooty eel, *Bascaniththys bascanium*, and the speckled worm eel, *Myrophis punctatus*.

Eels were prevalent along the 1.6 km of shoreline examined, and occurred from the water's edge to the most recent high tide mark located ~1.5 m up the face of the

moderately sloping beach. Most eels found on the beach were dead and lay totally exposed on the sand, while the few live individuals were lethargic and partially burrowed, tail-first, in the moist sand. Many eels were also observed along the expanse of the submerged (0.5 m water depth) tidal flat which extended several meters off the island's south beach, where dead eels lay either fully exposed or partially burrowed in the sandy substrate. Live eels on the tidal flat were found partially burrowed with their torsos waving rhythmically in the near calm waters. We estimated that greater than 75% of the eels observed on the tidal flat were dead.

The results of a visual survey conducted along two 50 m transects provided an estimate of 5 eels/m² of substrate. A cursory examination of a wide expanse of the tidal flat revealed estimated numbers of eels per square meter of substrate analogous to numbers estimated along the transects. We estimated the number of dead and dying eels along the 1.6 km section of the south shore at 8,000 individuals. We believe this to be a conservative estimate.

Identifications of dead and dying eels collected randomly throughout the survey area (N=41) indicated that B. bascanium and M. punctatus were present in roughly the same numbers in our samples (B. bascanium, N=23; M. punctatus, N=18). Total lengths of B. bascanium and M. punctatus ranged 133-474 mm and 104-155 mm, respectively. We were assisted in our identification of Bascanichthys bascanium by descriptive information provided by Leiby and Yerger (1980). No other species of eels were found.

DISCUSSION

Sporadic nearshore mortalities of demersal fish and crustaceans occur throughout the world (Loesch 1960). These events occur with some frequency and at many locations along the U.S. Gulf coast (Gunter and Lyles 1979) and are generally associated with blooms of phytoplankton, usually diatoms or dinoflagellates. Conspicuous outbreaks of discolored water caused by phytoplankton blooms periodically occur in Mississippi coastal waters (Perry et al. 1979; Eleuterius et al. 1981). Because many of these outbreaks are of short duration, they receive little or no attention and are rarely reported in the scientific literature. Phytoplankton blooms are often suggested as the cause of fish kills and "jubilees" which occur along the Mississippi coast (Perry and McLelland 1981). The phenomenon wherein fish and crabs crowd into shallow water along the beaches of Mississippi and Alabama during summer months is locally termed jubilee and was first reported by Loesch (1960) and later by Gunter and Lyles (1979).

Gunter and Lyles (1979) reported on the occurrences and probable causes of jubilees and fish kills along Bellefontaine Beach (Figure 1) located in Jackson County, Mississippi and remarked that such events were probably related to dinoflagellate blooms observed in the area. Fish kills associated with blooms were generally initiated in the early morning hours between midnight and daylight and occasionally continued into the day (Gunter and Lyles 1979). The largest fish kill observed by Gunter and Lyles (1979) along the Bellefontaine shoreline extended for a distance of about 8 km and "perhaps further". Bellefontaine Beach is located ~5.0 km east of Deer Island.

The specific cause(s) of the fish kill we observed was unknown, however, the event apparently had been on-going for several hours. Upon first arriving at the scene we speculated that the fish floating along the shoreline were by-catch from shrimping vessels working in the Mississippi Sound, but we quickly realized that the profusion of live, albeit languid, fish and crabs crowding the water's edge, the abnormally high numbers of dead and moribund eels blanketing the tidal flat and the presence of highly discolored water signalled a fish kill was in progress. The fact that eels had uncharacteristically emerged from their burrows en masse along the tidal flat during daylight, many ultimately to die, indicated the presence of unfavorable conditions.

Since our visit to the site of the fish kill was purely one of an inquisitive nature, we were without water sampling instrumentation and biological collecting gear and, therefore, were unable to measure water temperature and dissolved oxygen or to sample the discolored water for the presence of diatoms or dinoflagellates. The salinity of a small sample of water collected at the site and brought to the laboratory measured 6.3‰. Plans to return by skiff to the island later in the day for a more extensive investigation were curtailed by severe weather and rough seas. Inclement weather also prevented us from returning the following day (19 June) as well.

On the afternoon (1400 h) of 18 June we also inspected ~1.0 km of southern shoreline on the eastern end of the island and found no discolored water or indications of a fish kill. We did not examine the western end of the island, however it was reported to us that on the morning of 18 June a Biloxi fisherman "picked-up" more than 400 live flounders near the shore in "dark water" along the western end of the island's south beach, however, the fisherman made no comments regarding any sightings of dead or dying fish (Pat Kaluz, Biloxi Harbor Bait and Fuel Dock, personal communication). Although we observed a few fish floating at the surface of the water westward of the area we examined, we did not investigate, however, we believe it possible that the fish kill extended to the island's western end. To our knowledge no other accounts of discolored water or dead/dying fish within the vicinity of Deer Island were reported.

Perhaps the kill we witnessed during the morning of 18 June was a result of a localized, short-term phytoplankton bloom as suggested by the highly discolored water, however we did not detect the odor of decaying phytoplankton or hydrogen sulfide gas which reportedly often accompanies bloom related fish kills (Connell and Cross 1950; Gunter and Lyles 1979; Harper and Guillen 1989). Interestingly, one of us (RPD) previously had visited the identical area of the south shore on 17 June, the day prior to the episode, and observed no indications of a fish kill or discolored water. Jubilees that occur along the shores of Mobile Bay, Alabama usually develop rapidly in early morning hours before sunrise (Loesch 1960).

During a return visit to the kill site by one of us (RPD) on 20 June no discolored water was observed within the area. On that occasion water temperature and salinity were measured at 20° C and 7.2‰, respectively. Desiccated and partially decomposed carcasses of eels and other fishes were found widespread along the shoreline and tidal flat. No living eels were observed.

Gunter and Lyles (1979) reported that during three different jubilees along Bellefontaine Beach, menhaden, hogchokers, stargazers, croakers, hardhead catfish and "lots of eels" were either "sluggish" or dead and dying in either yellow-brown or reddish water. Loesch (1960) reported that species typically found during jubilees which occurred along the shores of Mobile Bay, Alabama were demersal species such as crabs, stingrays, flounders and worm eels, however, he noted that mortalities were rare and that people were not reluctant to eat fish and crabs taken during such incidents. The fishes listed by Loesch (1960) and Gunter and Lyles (1979) were among the species we encountered off Deer Island.

The actual areal extent and the magnitude of the effects of the fish kill were unknown. We could not realistically determine how far off the beach the discolored water extended. It is possible that some of the fishes observed near the shore had actually died further off the beach and were washed up by the recent high tide. Due to restricted visibility we were unable to determine if eels beyond the seaward terminus of the 50 m transects had been affected.

Leiby and Yerger (1980) stated that species of *Bascanichthys* appear to be more common in Gulf coastal waters than the various collecting methods indicate, and recounted that, following a red tide kill in September 1974 which extended from Pensacola to Panama City, Florida, examination of deteriorated fish carcasses in the field revealed a minimum of 30 specimens of *Bascanichthys* per 100 m of beach. Christmas and Waller (1973) collected only one specimen of *Myrophis punctatus* during a fisheries sampling program conducted along coastal Mississippi during 1968-69 and remarked that the speckled worm eel was probably much more abundant than their samples indicated. The infrequent occurrence of both species in local collections is probably related to the types of sampling gear and methods used and the fossorial habits of *B. bascanium* and *M. punctatus*. We report that *B. bascanium* and *M. punctatus* were found in abundance in the nearshore waters of

the Mississippi Sound following a localized fish kill. Random collections (some removed from their burrows) of *B. bascanium* and *M. punctatus* from a partially submerged tidal flat off Deer Island showed that both species were members of the island's sandy south shore benthic community.

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Northern Record for the Zooxanthellate Scleractinian Coral *Siderastrea siderea* (Ellis and Solander) from the Gulf of Mexico

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NORTHERN RECORD FOR THE ZOOXANTHELLATE SCLERACTINIAN CORAL *SIDERASTREA SIDEREA* (ELLIS AND SOLANDER) FROM THE GULF OF MEXICO

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ABSTRACT We report a northward range extension of the zooxanthellate scleractinian coral *Siderastrea siderea* (Ellis and Solander) in the Gulf of Mexico. Several small, living colonies of *S. siderea* have been obtained in dredge samples from a site located at 29° 55.5' N, 087° 28.4' W in the northeastern Gulf of Mexico. Prior to these collections the northernmost occurrence of *S. siderea* in the Gulf of Mexico was reported as 27° 54.5' N, 093° 35.8' W, on the East Flower Garden Bank, in the western Gulf of Mexico. In the eastern Gulf of Mexico, *S. siderea* is not reported occurring on the west Florida shelf north of the Florida Keys-Dry Tortugas or approximately 24° 55' N.

INTRODUCTION

In 1986 and 1988, during three oceanographic cruises surveying hardbottom habitats on the continental shelf off Alabama and northwestern Florida, seven living colonies of *S. siderea* (Ellis and Solander) were obtained on three separate slabs of hard substrate, brought up in Capetown dredge samples, from a site located at 29° 55.5' N, 087° 28.4' W (Figure 1). The colonies are all small, ranging in size from 1.8 x 1.5 x ~0.2 cm up to 6.1 x 5.1 x ~0.3 cm (Table 1) and are an encrusting form with a flattened, dome-like skeletal morphology.

The location where the specimens were collected is in an area called the Trysler Grounds and is locally known as Big Rock. Hardbottom substrates in the Trysler Grounds are primarily constructed from bioclastic limestones. They are present as scattered clusters of low relief (up to 1.5 m) outcrops. These outcrops tend to occupy the slope portions or bathymetric lows associated with the hummocky relief of extensive sand patches or large, low-amplitude sand waves. The Big Rock site is in 34 - 35 m of water approximately half way down the northwestern slope of a substantial bathymetric low. A set of tabular outcrops, some partially covered with sand, have been observed at this site during both remotely operated vehicle and manned submersible surveys. Individual outcrops, up to 5 m across and with 1 m of vertical relief, appear to be aligned in two or more parallel, discontinuous rows 2 - 3 m apart. Some of the outcrops are jointed along two or perhaps three nearly vertical planes, giving them a blocky, fractured appearance. Surface sediments in this mid-shelf region are principally composed of medium to fine, well sorted sands mixed with various sized areas of coarse sands and shell gravels and make up part of the MAFLA sand sheet (Doyle and Sparks 1980).

Monthly average bottom water temperature and salinity values in this region of the northern Gulf of Mexico range from 23 - 27° C in the summer to 16 - 19° C in the winter (Thompson and Leming, 1978; U.S. Department of Commerce, 1985; Brooks 1991) and 34.0 - 36.5 ppt year round (Darnell and Kleypas 1987; Brooks 1991), respectively. Extreme bottom water conditions in the vicinity of Big Rock, obtained over the period 1974 to 1990 from CTD vertical profiles taken during periodic cruises (unpublished data) and a moored instrument array (Brooks, 1991), range from 13.1° C in December, 1989 to 29.4° C in September, 1989 and 30.2 ppt in June, 1979 to 36.7 ppt on a number of occasions. Water clarity is generally high but intervals of poor light penetration do occur (Manheim et al. 1972; Steward 1981). Turbid conditions have been observed to develop in the upper water column during periods of both high runoff from the Mississippi River or regional watersheds and high biological productivity and in the lower water column during synoptic scale, wind-wave resuspension events (e.g. tropical cyclones or cold-air outbreaks) or from the importation of a nepheloid layer formed in an adjacent shelf area.

DISCUSSION

Prior to these collections the northernmost occurrence of *S. siderea* in the Gulf of Mexico was reported as 27° 54.5' N, 093° 35.8' W, on the East Flower
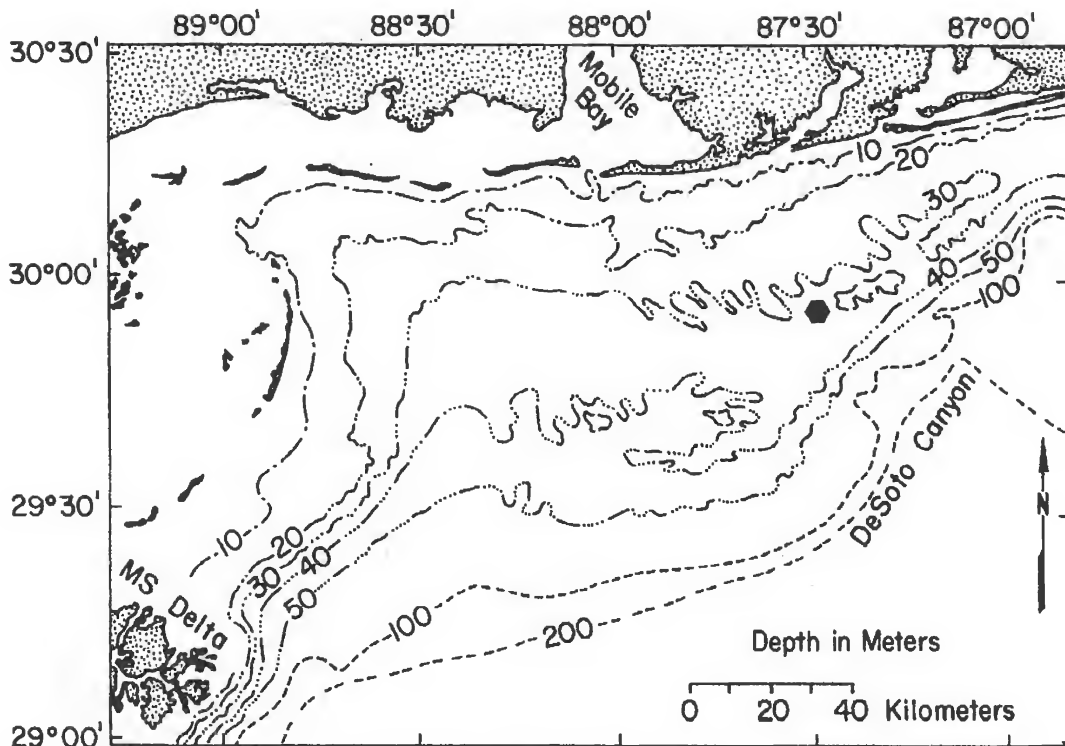
Figure 1. Location of Big Rock on the Alabama-northwest Florida continental shelf, northeastern Gulf of Mexico.

TABLE 1

Sampling dates and dimensions of *Siderastrea siderea* colonies collected at Big Rock (29° 55.5' N, 087° 28.4' W; water depth 34 to 35 m) on the Alabama-northwestern Florida continental shelf. * - archived as specimen No. 3766-1904 in the Marine Environmental Sciences Consortium Reference Coral Collection.

Colony	Date	Cruise	Dimensions
1	July 13, 1986	RSC-14	4.5 x 3.4 x ~0.3 cm
2	July 13, 1986	RSC-14	3.3 x 2.8 x ~0.2 cm
3	July 13, 1986	RSC-14	2.8 x 2.5 x ~0.2 cm
4	July 13, 1986	RSC-14	1.2 x 0.9 x ~0.2 cm
5	August 14, 1988	RSC-22	6.1 x 5.1 x ~0.3 cm*
6	August 14, 1988	RSC-22	1.8 x 1.5 x ~0.2 cm
7	October 11, 1988	ACSESS I-88	4.8 x 3.6 x ~0.3 cm

Garden Bank (EFGB), at the shelf break off the Texas-Louisiana coast in the western Gulf of Mexico (Bright et al. 1984; Rezak et al. 1985). Colonies can exceed 5 m in diameter (Gittings personal communication) and have been collected and/or observed at water depths from 21 - 50 m (Bright et al. 1984). Water temperatures measured at the EFGB from 1990 to 1995, at 19 m on the high diversity portion of the reef, ranged from 18.5 - 30.2° C (Gittings personal communication). These observations are consistent with the annual range of near-surface water temperatures (18 - 32° C) reported for this region by Etter and Cochrane (1975). In the eastern Gulf of Mexico *S. siderea* is not reported occurring on the west Florida shelf north of the Florida Keys-Dry Tortugas (FK-DT) or approximately 24° 55' N (Jaap and Wheaton 1975; Wheaton and Jaap 1988; Jaap et al. 1989; Chiappone and Sullivan, 1994). Colonies up to 1 m in diameter have been observed in the Florida Keys (Aronson personal communication). Water temperature extremes at the FK-DT range from 14 - 38° C while monthly mean values are between 18 - 30° C (Jaap 1984; Porter 1987).

Although the generally accepted lower temperature range for coral reef development is 16° - 18° C (Vaughan and Wells 1943; Levinton 1992) some hermatypic coral species, in non-reef building environments, have thermal threshold tolerances considerably lower (e.g. Wells 1955; Squires 1966; McCloskey 1970; Veron 1995). *S. siderea* is included among these species. For example, Macintyre and Pilkey (1969) and Macintyre (1970) report *S. siderea* in water depths of 20 - 40 m in Onslow Bay off North Carolina (approximately 34° 28' N) where winter bottom water temperatures can remain below 16° C for up to three months and values as low 10.6° C have been recorded. Therefore, the presence of *S. siderea* in the cooler waters of the continental shelf off Alabama and northwestern Florida, is not surprising. In addition, since *S. siderea* is a gonochoristic broadcasting species (Szmant 1986), transport of competent larvae, produced from colonies in reefs of the Yucatan Peninsula shelf, the Caribbean Sea and even the FK-DT area to this region of the Gulf of Mexico, can readily be accomplished during favorable northward intrusions of the Gulf Loop Current.

However, no living colonies or skeletal remains of *S. siderea*, or any other zooxanthellate scleractinian corals, have been found or observed on hard substrate during dredging, trawling, manned submersible or Scuba diving operations at numerous other inner and mid-shelf sites in this region of the Gulf of Mexico. We speculate that for the sites shallower than 34 - 35 m colder winter water temperatures, longer intervals of decreased water clarity, frequent periods of sediment abrasion associated with high wind-wave events and storm-driven sediment burial-exhumation cycles combine to prevent successful recruitment and/or survival. As for the sites at depths greater than 34 - 35 m the dominant factor is likely insufficient light intensity. The absence of *S. siderea* from the Florida Middle Ground (28° 35' N, 084° 16' W) (Grimm and Hopkins 1977), as well as other sites located on the West Florida shelf, has yet to be explained.

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A Study of Factors Influencing the Hatch Rate of *Penaeus vannamei* Eggs. III. Presence of the Female After Spawning

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A STUDY OF FACTORS INFLUENCING THE HATCH RATE OF *PENAEUS VANNAMEI* EGGS. III. PRESENCE OF THE FEMALE AFTER SPAWNING

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ABSTRACT A comparison was made of the hatch rate (percent hatch) of *Penaeus vannamei* eggs. The study was comprised of 100 spawns from mated *Penaeus vannamei* females. In one treatment, 50 female shrimp were removed from the isolation spawning tanks after spawning occurred but prior to hatching of eggs, producing 49.7% mean hatch rate. In the other treatment, 50 female shrimp were left in the tanks until after the eggs had hatched, producing an average hatch rate of 35.0%. A significant difference in the hatch rates of eggs was observed between spawns with and without presence of the female at time of hatching (P < 0.0135).

INTRODUCTION

Commercial seed production for shrimp aquaculture has been accomplished by captive reproduction. Mated ovigerous female shrimp are usually removed from large maturation tanks and placed in separate spawning tanks. In the isolation spawning tanks, females may be spawned singly or in groups. The spawned shrimp often are not removed until the next day and in some cases even after the eggs have hatched, approximately 12 hours after spawning. Females can also be spawned in the same large tanks in which maturation has occurred (Simon 1982, Chen et al.1991), and variation of this scenario could be developed for large-scale commercial use. Several researchers have recommended removal of the female after spawning. Kittiwattanawong et al. (1990), working with *P. monodon*, recommended that the female be removed in order to reduce the incidence of disease transmittal to the newly-hatched larvae. Cook and Murphy (1966), working with *P. aztecus*, removed the female after spawning, reportedly to prevent the female from ingesting the eggs. In addition to the practice of isolating females in separate tanks for spawning, some facilities rinse and transfer eggs to clean water hatching tanks. As data was unavailable on the effect of removing the female after spawning, the present study was undertaken with *P. vannamei*.

MATERIAL AND METHODS

Female shrimp were matured and mated in large commercial-sized tanks operated according to standard practices (Ogle 1992). In the evening, female shrimp were "sourced" (checked for the presence of a spermatophore) and removed from the maturation tank if mating had occurred. Each shrimp was placed in a separate spawning tank and checked several hours later for spawning. The circular 1 m² fiberglass spawning tanks were 0.6 m deep and 1.12 m in diameter and contained 200 l of seawater obtained from Davis Bayou in the Mississippi Sound. The seawater was settled to remove solids and the ambient salinity was increased to 30 ppt by adding an artificial sea salt (Marine Environment, San Francisco, CA). The water was pumped through a 5 micron filter. Seawater was changed and spawning tanks cleaned after each spawning. Moderate aeration was provided by a single airstone.

The study was conducted over a two-month period, with females chosen randomly for either of two treatments. In one treatment, 50 females were removed from the spawning tanks and returned to the maturation tank after spawning. In the other treatment, 50 females were left in the spawning tanks until the next morning when the eggs had hatched.

Hatch rates were estimated from the number of eggs at spawning and the number of nauplii after hatching. Numbers were determined by subsampling. Water in the spawning tank was stirred and five 10 ml subsamples were collected. Subsamples were taken from the four compass directions and the center of the tank, transferred to a petri dish and the number of eggs or nauplii enumerated. Data were averaged and analyzed by ANOVA and significant (P< 0.05) differences noted.

On one occasion, water samples were taken after hatching, one from the tanks with the female and one from the tanks without a female. A control sample was obtained from a tank with no female shrimp or eggs present. Samples were analyzed for pH, total ammonia and nitrite in accordance with U.S. Environmental Protection Agency (1983) procedures.

RESULTS

Hatch rates averaged 49.3% (S.E. 3.50%) and varied from 2.7% to 96% for tanks in which the females were removed after spawning. Hatch rates averaged 35.0% (S.E. 4.30%) and varied from 1.5% to 97.2% for the tanks in which the females were not removed. A significant difference in the hatch rates of eggs was observed between spawns with and without presence of the female at time of hatching (P<0.0135).

Water quality deteriorated slightly due to the presence of the female as compared to a control tank without shrimp (Table 1). Nitrogen values of the water in the control tank were higher than expected for oceanic water. This may be due to the use of eutrophic estuarine water for the hatching studies. The pH declined and total ammonia and nitrite increased slightly for spawning tanks in which the females were not removed.

DISCUSSION

The presence of the female might have been expected to decrease the hatch rate of the eggs due to deterioration of the water quality, which apparently was the case.

It can be speculated that the lowered hatch rate associated with females left in spawning tanks could be related to metabolic products of the females, e.g., feces and ammonia in the culture water, which would contribute to bacterial, fungal, and other microbial attacks on the eggs themselves. If this is the case, it is possible that bacterial or fungal inhibitors may be beneficial.

Since the presence or absence of the female after spawning created a significant effect on the hatch rate, the decision to remove the female must be determined by the needs of the individual facility. Commercially, it appears to be easier and cheaper to mass spawn shrimp, leave the females in the tank after spawning and harvest the larvae in mass. This process involves the use of one tank instead of several tanks which greatly reduces the time required to harvest and refill. One disadvantage of this method is the inability to determine individual female performance, which is known to be highly variable. McGovern (1988) and Oyama et al. (1989) reported that a small percentage of females are responsible for the majority of nauplii production. Researchers will continue to spawn shrimp individually in order to collect data on

performance and attempt to understand the variability. Small individual spawning tanks are easier to clean and treat and allow selection of the best individual spawns. Additionally, cleanliness or disease transmittal concern have led some to remove the females (Kittiwattanawong et al. 1990). However, this approach requires maintenance of a large number of spawning tanks. The use of more tanks in limited space may necessitate use of less than ideal size tanks, therefore reducing the overall hatch rates (Ogle 1995). The present study shows that significantly lower percent hatch occurs when females are left in the spawning tank through hatching. This provides additional information for researchers and commercial facility managers to use to optimize spawning systems in which many factors influence results.

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TABLE 1
Water quality after 24 hours

		Total	
	pH	Ammonia (ppm)	Nitrite
No shrimp or eggs present	8.11	0.323	0.076
Female removed after spawning	8.12	0.282	0.073
Female not removed after spawning	7.98	0.384	0.105